COOPERATIVE DEVELOPMENT, DEMONSTRATION AND EVALUATION OF INTEGRATED TRUCK-SHOVEL OPERATIONS AND MANAGEMENT SYSTEM IN PRODUCING SURFACE COAL OR OIL SANDS MINES - PHASE I

FINAL REPORT
BY:

WENCO INTERNATIONAL MINING SYSTEMS LTD.

Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy Mines and Resources Canada. This work was supported (in part) by the Federal Panel on Energy R&D (PERD).

DSS FILE NO.: 14SQ.23440-7-9148

DSS CONTRACT SERIAL NO.: 23440-7-9148/01-SQ

CANMET PROJECT NO.: 7-9148

CANMET SCIENTIFIC AUTHORITY: Dr. V. Srajer

289 pp

MICROMEDIA

DATE: September 22nd, 1988

90-00182/

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1. Introduction

This report presents the results of Phase I of the project to develop, demonstrate and evaluate an integrated truck/shovel management system. In Phase I, Wenco identified existing technology and set out specifics of the work to be involved in the Phase II: the development and testing of the selected components.

The overview in Section 3 provides a comprehensive picture of the project, including the history behind the development of the terms of reference. The participants are identified, and their roles described. A description of each of the four phases is provided along with a timetable.

The chapter on the mine requirements survey deals with the interviews conducted with various mining companies to obtain their input on their perceived value of various current and proposed technology associated with the project.

The technology survey and recommendations in Section 5 summarizes the investigations into the six technical areas of the integrated management system: simulation, dispatching, equipment information, data transfer, location monitoring and the data base. For each of the six components, this section discusses the objectives, summarizes the available technology, recommends a supplier, and estimates costs and benefits. Considerably more detail on each area is included in the Appendix for readers wishing to explore any particular area further.

Section 6 outlines the program for Phase II of the project: the development and testing of the six technical areas recommended in Phase I. The programs for Phases III and IV are discussed in Sections 7 and 8 respectively. Section 9 discusses anticipated costs and benefits, from several points of view.

2. Executive Summary

Over the previous four months, technical and research staff at Wenco International Mining Systems Ltd have undertaken a review of mine operators' requirements for the various components proposed for an Integrated Truck and Shovel Operating and Management System, and have reviewed available technology in each field. We evaluated the proposed development, giving weight to expressed need, cost effectiveness and common standards that would suggest the practicality of eventual integration.

Phase II of the project will see each module developed using communication and computer standards that are established herein. Each module will then be tested in the new format. It is our recommendation that the following components be included in Phase II development and testing:

- Ad Opt (Montreal) — Mine simulation and dispatching
- Caterpillar (Peoria) — Payload control
- Mobiltex (Calgary) — Data communications, location monitoring
- Ropec (Vancouver) — Vital signs monitoring
- Wenco (Richmond) — Database, vehicle health monitoring study, system specifications for integration, project management

The integrated system is scheduled for completion by October, 1989 and the demonstration and evaluation phase to run from then until November, 1990. The project cost is detailed in the following schedule:

Project costs and schedule

Phase I	67,454	Complete
Phase II	1,443,518	November '88 - April '89
Phase III	234,900	April '89 - October '89
Phase IV	1,216,294	October '89 - November '90
Total project:	$2,962,166	

2. Sommaire Executif

Durant les quatre premiers mois, le personnel technique et le personnel de recherche de Wenco International Mining Systems ont faitla revue des besoins pour les différentes composantes d'un Système Intégré de Gestion et d'Utilisation des Pelles et des Camions dans un contexte d'exploitation minière. Ils ont en outre évalué la technologie disponible pour chaque composante. Ils ont évalué les développements proposés, en accordant des priorités aux différentes requêtes présentées, en établissant le coût/bénéfice, et en définissant les standards qui faciliteraient l'intégration des différentes composantes.

Durant la phase II du projet, les différents modules seront développés en utilisant les standards de communication et de matériel informatique présentés ici. Chaque module sera alors testé selon les nouvelles spécifications. Nous recommandons pour la réalisation de la phase II, développement et test, l'utilisation des composantes fournies par les groupes suivants:

Ad Opt (Montréal)	Simulation et assignation
Caterpillar (Peoria)	Contrôle de charge des camions
Mobiltex (Calgary)	Communication radio, détection des déplacements
Ropec (Vancouver)	Détection des signes vitaux
Wenco (Richmond)	Bases de données, analyse des signes vitaux, spécifications pour l'intégration des composantes et gestion du projet

L'intégration des composantes du système devait être complétée en octobre 1989, les phases de démonstration et d'évaluation devraient durer jusqu'en novembre 1990. Les dates de réalisations et les coûts sont présentés ici:

Phase I	67,454	Complétée
Phase II	1,443,518	de novembre 88 à avril 89
Phase III	234,900	de avril 89 à octobre 89
Phase IV	1,216,294	de octobre 89 à novembre 90
total	$2,962,166	

3. Project Overview

3.1 Terms of Reference

In August 1987, CANMET issued a request for proposal (RFP) with the full title "Cooperative Development, Demonstration and Evaluation of Integrated Truck/Shovel Operating and Management Systems in Producing Surface Coal or Oil Sands Mines". A copy of the RFP is included in Appendix X. Wenco International Mining Systems Ltd. was selected as the successful bidder.

As envisioned by CANMET in their request for proposal, the Integrated Truck-shovel Operating and Management System will involve the bringing together of existing technologies in five key areas, the further development of those technologies, the integration of those dissimilar parts into a cohesive whole and finally the demonstration of the resulting system. The five components described were:

1. A simulation model, for shift planning and 'what if' analysis.

2. An automatic truck dispatching system, to optimize equipment use.

3. A location monitoring system, for dispatch information and control.

4. An equipment information system, for equipment protection.

5. A data communications system, to provide real time access and control.

It is the overall purpose of this work to significantly extend the state of Canadian technology in the application of computers to the mineral industry. The Integrated Truck-shovel Operating and Management System is to provide an unprecedented degree of information and control for the ultimate purpose of optimizing surface mining operations. Optimum mine operation is defined as the production of both mineral and associated waste, in planned amounts and grades, at the lowest possible cost per unit and without modification of the mine's labour and safety practices.

The Wenco proposal complied with the original terms of reference as set out in the RFP. However, due to the varied and complex nature of the project, Wenco and CANMET revised the original terms of reference to reflect the fact that some of the technology proposed for the project was either untried or, may not meet the requirements of some of the mine operators. The ma-

jor change to the terms of reference was to obtain further opinions from the mines on their needs as regards truck and shovel management. On the basis of this information, subsequent phases could proceed with the knowledge that the value of their work would be maximized.

3.2 Participants

The project is a cooperative effort involving three groups:

1. CANMET, as the agency charged with the promotion of technology development for the Canadian mining industry.

2. Mine operators, who are the end users of the products, and whose cooperation and participation ensures that the work will be of maximum benefit. Two mines are actively involved:

   Suncor, Inc., Fort McMurray, Alberta
   Westar Mining Ltd., Greenhills Mine, Elkford, B.C.

   These mines have participated by providing their input on requirements that the integrated system should meet, and reviewing and approving the direction of the project. Their mines will be used as the sites for the individual testing of the various components, and for testing of the integrated system.

3. Wenco International Mining Systems Ltd., as the project coordinators and suppliers of a major part of the expertise and products required to integrate the various technologies for the truck/shovel management system.

3.3 Project Phases and Timetable

Wenco International Mining Systems Ltd proposed to bring together a group of companies who would jointly undertake to extend their present technology in a direction that was compatible with Wenco's Production Monitor & Control System (PMCS). As a preliminary phase, Wenco undertook to identify existing technology and set out specifics of the work to be involved in the second phase, development and testing of the selected components. This report presents the conclusions and recommendations resulting from that Phase I work.

Phase two of the project will involve the development and testing of each of the selected components of the Integrated Truck-shovel Operating and Management System. Phase three will

integrate these components and test them in an operating mine. In Phase four, the integrated system will be operated for a one year period in a controlled situation for full evaluation, and demonstration to other researchers and mine operators. As anticipated, examination of existing technology during the first phase has resulted in changes to the scope of the work. Some components of the Integrated Truck-shovel Operating and Management System are more fully developed than others; some thought to be candidates, are now considered incompatible with the main body of work.

4. Mine Requirements Survey

4.1 Scope

The revised statement of work provided by Canmet sets out a description of six subsystems or modules that are to be individually developed and tested. These subsystems are then to be combined into an integrated surface mine management and information system, then demonstrated. Each of the modules and the integrated system are to be evaluated in operating mines.

The original Request for Proposal envisioned the spending of equal sums on each of five elements of the system. Mine operators and owners of technology alike expressed concern about this approach due to the disparity between the states of the art presently existing in each field, and questions regarding whether the results would be valuable.

Accordingly, this mine requirements survey was undertaken for the purpose of ensuring that proposed subsequent work in the development, testing and evaluation of an integrated truck shovel management system would be relevant to mine operators needs, and as a necessary step in securing cooperation from mine operators in the testing and evaluation phases.

The primary purposes of the Phase I project, of which these requirements form a part, is to determine:

- Which among these elements are supported by needs expressed by mine operators?
- What technology exists now in each field and which of several options will best meet the overall project objectives?
- What will it cost to assemble or develop the technology to the point of practical demonstration, given the above?

This mine requirements survey attempts to answer the first of these questions.

4.2 Methodology

The specific survey methodology used is what is generally referred to as an unstructured, undisguised questionnaire. This consisted of meeting with the mine personnel to obtain attitudes and opinions through open ended responses. The survey also

served to identify the degree of awareness and knowledge of the subject.

Secondary sources from literature searches were used to gather background information on the availability of and prior experience with some of the technology.

It is important to understand what can and cannot be accomplished in a requirements survey of this type. To understand the limitations requires an understanding of the individual being interviewed and the environment he operates in. In this regard, some of the key factors that should be considered in assessing the results are:

1 The persons to be interviewed often had an incomplete knowledge of the technology and how it could help them.

2 Mine personnel had uncertain knowledge of the cost/benefit relationship of some of the new technology available.

3 As with any attitude/opinion survey, there were personal biases which have to be considered. These biases could be the result of senior management attitude toward technical innovation, their own attitude toward technology formed by good or bad prior experiences with new technology, and how the technical innovation affected his particular group, whether it be production, maintenance or engineering.

The observations and conclusions reported herein are a reflection of the opinions expressed by mining engineering and operations staff at 12 mines.

Very few clear conclusions or consensus could be drawn, even among various staff members at a single mine.

4.3.Requirements

4.3.1 General

It is expected that subsystems will be unequally weighted in terms of their desirability, and probably their development, implementation and testing costs. This becomes more evident as the investigation of available technology proceeds, as the perceived needs of the mine operators become more clear, and as the costs and benefits of options are determined.

4.3.2 The Integrated System

While integration is a valid objective, mine operators stress that each module must be capable of operating in a mine environment on a stand alone basis. Certain mines may require only one of the elements, while others may require different combinations of the integration elements.

Other preferences expressed most frequently are summarized as follows:

- Computer hardware most preferred are 80286 and 80386 based micro computer(s).

- User interfaces should be similar for all modules, emphasizing few keystrokes and standard key functions among all modules. Point and shoot devices, such as a mouse, are desirable where applicable.

- Communications strategies should be similar for each module, and at the minimum, each module will be capable of communication with all other modules that it might be required to address.

4.3.3 Simulation

There are two primary objectives of the simulation sub-system. They are to provide a very short range operating strategy to guide the dispatching module and shift supervision during the course of this shift, and to provide a tool for longer term analysis such as the evaluation of an equipment purchase (What if?).

- Input parameters are:
  Mineral quality by working face
  Required blend (range)
  Loading time by individual shovel and truck fleet combination
  Travel time by truck fleet and route segment
  Trucks available, by fleet
  Shovels available, and working faces available to each

- The simulation system shall obtain current operating times, and other equipment performance characteristics needed, from real time data gathered during a recent shift through the dispatching program.

- For longer range planning and what if analysis, further input requirements include mine wide constraints, such as total trucks and shovels by fleet and availability by fleet.

- The simulation program must provide a reliable forecast of results when any of the operating parameters are changed.

- For the guidance of the dispatching module, produce a number of operating strategies that meet shift objectives for quality and production.

- Report an identification number for the best (n) workable plans produced, in order of production resulting from each.

- Display a key indicator for each shovel, such as percentage of waiting time, digging time or truck waiting time, upon which the operator can base his choice of plans. He will accept lesser production for uniformity of this indicator, in preference to extremes which may not be achievable.

- Produce input required by the dispatching module to cause it to operate according to the selected strategy.

4.3.4 Dispatching

Two separate and distinct dispatching systems are required, each to serve a different purpose. The objective of the first is to minimize equipment waiting time. The objective of the second dispatching subsystem is to optimize production results among all working faces (Maximum production with minimum travel) while maintaining mineral blend into the primary crusher within the desired range. Both will:

- Use information received by radio link from operating equipment to determine loading times by shovel / truck fleet, travel times over each route segment for each truck fleet, truck status and location, etc.

- Provide fall back positions, to ensure continued reasonable operation despite failures in any of the system's components.

- Provide the full range of dispatcher displays currently offered by PMCS, to display and control production and operating factors.

- Dispatch trucks according to the mines needs and policies.

The strategy that is required to include blend control as a constraint in the dispatch decision process will include the following features:

- Accept and use output from the simulation program to define the operating objectives of this shift.

- Dispatch trucks according to the strategy supplied by the simulation program to achieve the objective stated above.

- In the event changes occur to prevent the maintenance of the required blend, such as a key shovel becoming unavailable, warn the dispatcher.

4.3.5 Equipment Information

While there is great interest in this area, there is no clear consensus on the preferred features. The mine operators expressed a variety of needs, and the features most requested were:

- Protection of equipment from damage or failure due to abuse, loss of fluids, and other factors.

- Provide detailed operating time information for the use of mining engineers and maintenance planners.

- Reporting of the operating information required by the dispatching program in real time.

This system is expected to monitor operating, maintenance and equipment performance data to serve the twofold purpose of providing maintenance staff with valuable data upon which to base their efforts, and feeding actual performance data to the simulation and dispatching functions.

There is a demand for payload weighing ability, both to control loading to the rated limit and for accurate production reporting. This capability should provide shovel operator guidance while the truck is being loaded.

Several kinds of systems, each with different characteristics, are identified below and each has its supporters in the mining community.

- On-board monitoring systems that check pressures, fluid levels and temperatures, warning the operator of any abnormality. They may or may not automatically shut the engine down in threatening conditions. There is a significant desire for this function, with 50% of those expressing interest also suggesting downloading information by radio for use either as emergency control or simply for convenience of data capture. (Ropec and others)

- Monitoring and recording of truck payloads, detailed operating cycle time information such as speed, forward/reverse shifting, etc. This information provides payload guidance to the shovel operator. There are few proponents, primarily because of lack of confidence in payload measuring devices, but this approach can provide the truck status information needed to support fully automatic, driver independent dispatching. Those interested usually request radio downloading.

- Shovel based payload control systems, providing payload control and accurate measurement of loading times. This was interesting to most operators, and attempts to use such systems had been made at several of the mines contacted. Payload control from the shovel is less costly and less damage prone than from trucks. It is perceived to be less accurate, too.

- There is a considerable desire for a tire control system, which may or may not be an appropriate part of this section. Functions are to record tire life history as a means to cost reduction and tire life extension.

4.3.6 Data transfer

It is the objective of the data transfer system to handle all of the data radio needs of the integrated system in an efficient manner, and in a way that doesn't interfere with the voice radio system. The following points were raised in the survey:

- It is desirable for communications involved in the dispatching function to occur immediately, whenever there are any data to transmit, using an interrupt strategy.

- Data not necessary for real time processing may be downloaded periodically using a polling technique.

- Voice and data should be carried on separate frequencies, and probably use separate radio sets to avoid frequency switching and message delays. (For the purpose of this report and the resulting system, voice radio will not be considered a part of the integrated system. Each mine has a voice network, and no incentive to change.)

- It may be practical to use a separate frequency (and radio) for each function, rather than attempt to force the variety of technologies into one mold. We note that the various technologies under examination each

have a functional communications strategy that works, and each has a frequency crowding limit of use.

4.3.7 Location monitoring

It is the objective of the location detection strategy selected to provide a current view of monitored equipment in relation to a map of the mine, and to provide such location information to the dispatching program as is required for it to perform its work.

- At the minimum, data will be provided to the dispatching computer at points in the truck cycle when dispatch decisions are to be taken.

- It is desirable for sufficient truck movement information to be gathered and reported, that the trucker need not be required to enter and transmit status or location information to achieve effective dispatching. At the mine operator's discretion, dispatching can be fully automatic or utilize truck driver entered data.

- Represent equipment location on a high resolution screen carrying a graphics map of the mine.

4.3.8 Data base

It is the objective of the selected data base system to store information gathered from the various subsystems hereof, and to provide ready access to that information in a form useable to mine operators.

- The presence of the data base must not degrade the performance of the PMCS monitor.

- This suggests that the data base will be updated by an independent process, or processes, resident on some machine other than the machine on which the PMCS MONITOR is run. This further implies that there must be a transaction processor, or server, to put things into, and take things out of, the data base.

- The data base must be accessible by several users simultaneously. At a minimum this means that any number of users can read information at the same time as other users are reading or writing. It is acceptable that only one user can write at a time. A transaction processor, or server, would deal with this requirement by queuing requests.

- The data base must provide users with a query/report writing facility that is ad hoc in nature. This means that users of the facility can create their own programs and reports.

- The data base must support the integration of the other project components and provide a vehicle for exchange of information between them. Other project components are taken to mean:

    Operation Modelling & Simulation
    Vehicle Information
    Dispatching
    Vehicle Location

- The data base will not necessarily replace the current PMCS data structure which is specially designed for MONITOR's and MIS's needs. In fact, due to the inherent efficiency of the current data structure, it is very probable that the data structure will not be replaced by the data base facility.

5. Technology Survey and Recommendations

5.1 Simulation

5.1.1 Objectives

There are two primary objectives of the simulation sub-system. The first is to provide a very short range operating strategy to guide the dispatching module and shift supervision during a given shift. The second is to provide a tool for longer term analysis such as the evaluation of an equipment purchase.

The simulator's function is to produce operational truck/shovel shift plans together with the plans' expected results. The program simulates the operation of the mine's trucks and shovels and produces plans for their optimum utilization Given a mine layout and a set of production targets, the simulator will place the shovels in the mine and estimate the required truck volumes in such a way that the production targets will be realized with minimum cost.

The proposal (Wenco, 1987) outlines a four part simulation development plan. Parts I, II, and III will provide planning support directly to the first-line in-pit mine supervisors. Part IV will provide support for longer range planning (mine layout, equipment selection, etc).

Part I: Optimal shift plan. An interactive program will calculate a set of optimal shift plans. Shovel locations, materials, and digging rates will be matched with truck frequency and routing. The calculated plans will be such that the shift's production and quality targets will be realized.

Part II: Optimize maintenance time. Scheduled and unscheduled maintenance time is to be added to the program developed for Part I. The shift plan targets are to be met even when some equipment is unavailable.

Part III: Interface a shift plan to the real-time dispatching algorithm. The dispatching algorithm must dispatch trucks in such a way so that the shift plan is realized. Therefore, the plan must be made available to the dispatching algorithm.

Part IV: Longer term economic simulation. This encompasses the integration of all information from the previous Parts. The data is to be statistically reduced to a set of factors that will be used with economic and

blending factors to optimize the mine plan on an economic basis over a longer time horizon.

The resulting programs are to be interactive so that input parameters can easily be changed, that is, "what if" scenarios can be quickly investigated.

5.1.2 Available Technology

Several simulation methods and procedures were reviewed. The following is a brief description of the algorithms and operating considerations of a number of these. Further detail is to be found in Appendix III.

Ad Opt

This simulation methodology is described in the literature (Soumis et al 1988). The objective function of the program determines all possible combinations of equipment utilizations that will meet the shift objectives within current mining constraints, rank them in order of production volume and produce selected operational truck/shovel utilization plans together with the plans' expected results. The program simulates the operation of the mine's trucks and shovels and produces plans for their optimum utilization. That is, given a mine layout and a set of production targets, the simulator will place the shovels in the mine and estimate the required truck volumes in such a way(s) that the production targets will be realized with minimum cost.

The system comprises two programs. The first uses linear techniques to determine the set of solutions that meet the constraints and to predict resulting production. The second uses non-linear pseudo cost functions to force a solution (shift plan) near the center of the target range, and produce objective functions to guide a dispatching program.

Modular Mining Systems

This simulation program was written specifically to supply a dispatch algorithm with a optimum short term shift plan. It also supplies the in-pit supervisors with shift set-up decision support. The Ad Opt non-linear approach to solving the allocation problem would appear to yield marginally superior results, in a much simpler fashion.

While the logic was examined from the literature, it is noted that this program is not available independent of a Modular Mining Dispatch installation and is therefore not a candidate.

Other candidates

A number of simulation programs were investigated (Runge, 1983; Tu & Hucka, 1985; Chatterjee & Brake, 1981; Nenonen et al, 1981). All of them were not suitable for use in the Integrated Truck/Shovel Management System because they were designed to be used as mine planning tools and not as mine operational tools.

5.1.3 Recommendations

The strategy recommended for the Integrated Truck/Shovel Management System is to use the planning modules contained in Ad Opt's truck dispatch system as a base. Part II objectives (Maintenance planning) are not recommended to be pursued at this time.

This strategy is recommended because:

- This model already meets the requirements of Part I.
- This model already meets the requirements of Part III.
- The model uses a combination of Linear and Non-Linear programming. The non-linear techniques yield optimum solutions that are more stable in the real-time dispatching domain than linear techniques. This is due to that fact that the non-linear solutions trend towards the optimal solutions for all parameters. Linear solutions produce solutions whose parameters may sit at the extreme limit of acceptability (Soumis et al, 1988).
- Ad Opt's dispatch logic has been selected for the Integrated Truck/Shovel Management System's dispatch module. By using Ad Opt's simulation, a high degree of compatibility and integration is achieved.

5.2 Dispatching

5.2.1 Objectives

Two separate and distinct dispatching strategies are described, each to serve a different purpose.

The objective of the first truck dispatching strategy is to minimize waiting time for both trucks and shovels. Emphasis may be on shovels, trucks or both depending on whether the test mine is under or over trucked, or balanced.

Preliminary results will be measured by recording waiting times experienced over a base period, using the mine's usual truck allocation practices, then comparing the results over a similar period with the selected dispatch methodology in operation. Success will be measured by the application of a measure directly related to cost. Unit cost of product if available, otherwise BCM or Tonnes per gross operating hour.

The objective of the second dispatching subsystem is to optimize production results among all working faces (Maximum production with minimum travel) while keeping the plant's mineral blend within the desired range.

Incremental improvement in the measures mentioned above will be recorded. Since this strategy is also designed to provide control of product blend, variations from the planned blend will be statistically compared with the blend achieved without this control. If significant improvement is observed, the effect on processing plant efficiency and cost will be studied to quantify the value of this contribution.

Several dispatching algorithms are reviewed in this section. Additional detail and background discussion can be found in Appendix IV.

5.2.2 Available Technology

Wenco International

The algorithm currently used by Wenco's PMCS minimizes truck and shovel waiting time by dispatching trucks to the first available shovel; it permits mine supervisors to group shovels; shovels in a group share a pool of trucks. Shovel locations, associated materials and the number of trucks assigned to a shovel group are determined by operating staff based on real time information that is tracked by PMCS and presented to them on a video display terminal.

OBDAS

This method (Hagenbuch, 1987) is primarily concerned with minimizing equipment non-productive time. The method's core is described by the following quote: "the principal dispatching question to be answered is 'What piece of loading equipment or which dump site will need a truck the soonest and where can a truck get 'turned around' loaded or dumped 'the quickest?'" Similar in concept to the Wenco strategy, this procedure has not been implemented at the time of this writing.

Hauck

The method was developed in 1972 when computer hardware, computer software, and radio hardware were more primitive than today. It is a semi-automatic algorithm that required manual time input by the dispatcher. It should be noted that this method could, in principle, be upgraded to take advantage of modern technology, barring better alternatives.

Bonates & Lizotte

The method (Bonates and Lizotte, 1988) consists of an LP simulation algorithm coupled with a semi-automatic dispatching algorithm. It suggests a dispatch strategy to a human dispatcher. The dispatcher transmits dispatch assignments to the trucks via voice radio.

Ad Opt

The algorithm proposed by Ad Opt (Soumis et al., 1988) bases dispatching decisions upon the shift plan developed in the two step optimization and planning programs described in section 3 hereof. The effect of the chosen strategy is that the shift plan developed in the simulation and optimization procedures will be almost precisely met, given no change in equipment at work. Since such changes are inevitable, they are quickly accommodated by re-running the shift plan module, using the new equipment constraints.

Each time a truck requests a dispatch, the classic assignment problem is solved that involves the truck in question, all the trucks that will request a dispatch in the near future, and all the available shovels. The truck is dispatched in such a way as to minimize the difference between the planned and expected overall equipment waiting times. The expected waiting times are calculated using real-time moving averages of the in-pit operating times.

Modular Mining Systems

The method (White and Olson, 1976) consists of two LP sub-algorithms (loosely coupled) and a dynamic dispatching algorithm. LP 1: Solves the overall optimization problem, LP 2: Maximizes production, DP: Dispatches trucks.

The overall objective of the method is to maximize production, minimize rehandle and feed the plant with the target amount of material subject to blend requirements.

5.2.3 Recommendations

Two strategies are recommended for use in the Integrated Truck Shovel Management System. They are, first a deterministic strategy that minimizes waiting time (Wenco PMCS), and second, a more complex strategy that bases dispatch decisions on an optimized shift operating plan (Ad Opt).

The algorithm currently used by Wenco's PMCS (Sadler, 1988) is recommended because it is currently being used successfully in two mines; it is currently installed in PMCS; has proven capable of providing reliable baseline data for system evaluation and is available for enhancement.

The algorithm proposed by Ad Opt (Soumis et al., 1988) is recommended because it is has been successfully demonstrated in a mine; it remains stable when the mining situation changes; it's calculated optimal parameters trend towards optimal values smoothly due to the use of a non-linear optimization procedure.

5.3 Equipment Information

5.3.1 Overview

Equipment information systems, as referred to in this analysis, cover two areas that are related only indirectly: vehicle health monitoring, and production monitoring.

The results of both types of monitoring can be useful in the mine planning process. Knowledge of equipment productivity can aid in the selection of equipment in the production planning process. The mechanical status of the equipment is also useful to know since the equipment could be more efficiently scheduled for planned maintenance.

<u>Vehicle Health Monitoring</u>

Vehicle health monitoring records information related to the mechanical condition of the vehicle, and can be classified into two areas based on the use of the data provided:

1) vital signs monitoring

2) comprehensive monitoring.

Vital signs monitoring systems monitor parameters whose values are critical to the mechanical 'health' of the equipment. Such systems will provide a warning to the operator or other ob-

server that an action must be taken immediately or else serious and costly damage to the equipment will result. An example is engine oil pressure or temperature.

Comprehensive monitoring systems gather operating information for further analysis, generally by someone associated with the maintenance department of the mine. This can include information to be used for predicting the time of component failure based on observed trends in operating statistics, such as pump pressures. Component monitoring can be used for tracking performance and costs of various parts of the vehicle, such as tires, wheel motors, and any other component whose cost or function merits recording.

Production Monitoring

Production monitoring generally refers to the recording of data related to what the machine was made to do, such as recording truck weights, shovels production based on bucket weights, and drill productivity measured by metres drilled. This information is used directly by the production and mine planning groups to quantify results and to for production planning.

Equipment information systems cover a wide spectrum of activity and are of use to different persons in the mine organization. These are summarized in the table below:

	USED BY:			
MONITORING FUNCTION	Operations	Mine Planning	Maintenance	Equipment Operator
Production:				
- Real-time	X			X
- Historical	X	X		
Vehicle:				
- Vital Signs	X		X	X
- Comprehensive		X	X	

5.3.2 Available Technology

Microcomputer-based equipment information systems have developed either as an adjunct to a company's primary activity of vehicle manufacturing, or independently by smaller companies who have recognized the need for such devices.

The products of the following companies were examined:

ACET Ltd.
Advanced Electronic Systems Ltd.
Caterpillar
Interactive Sciences, Inc.
Philippi-Hagenbuch, Inc.
Pit Control
Ropec Industries Inc
Unit Rig - UNIPARS
Wabco
Wenco International

A detailed description and discussion of their products is included Appendix V.

5.3.3 Recommendations

The recommendation of a single product for field testing is not possible because many of the products in this category have functions that overlap in different areas, there are several groups of users to be addressed, and no single product meets everyone's needs.

Furthermore, the integration of all the systems studied presents technical difficulties related to data radio protocols and throughput. In general, information required in real time should not be integrated through the data radio link with information required on a periodic batch basis.

Accordingly, the following strategy is recommended:

i Test products that integrate readily both technically and with regard to the end use of the information.

ii Conduct further studies on systems directed at the maintenance group of the mine, specifically comprehensive vehicle health monitoring.

Vital Signs Monitoring

Since vital signs monitoring information is required in real time and is useful to production personnel, we recommend that it be integrated with the real time production monitoring information.

The Ropec Industries Inc. Engine Protection System is recommended for testing from this group. The demand for this kind of product has been demonstrated by mine operators, and several systems are in use or being installed by the mines.

The Ropec Engine Protection System provides immediate warning and a sequenced engine shutdown in emergency situations or when engine problems are identified. The system consists of a controller, annunciator, battery relay, and uses a network of sensors.

Engine parameters are monitored through the sensors. Signals received from the sensors are analyzed by the controller and a logical sequence of events leading to engine shutdown is initiated. In response to a signal from the controller, the annunciator visually and audibly warns the operator of the detected fault. If the fault is a non-emergency, the over-ride button may be used to give the operator time to move the equipment to a safe location before engine shutdown.

Payload Weighing Systems

Payload monitoring can be achieved either at the shovel or on the truck. Selecting a payload monitoring device is complicated by the following:

1. The shovel weighing devices are all made for rope shovels.

2. Most of the truck weighing devices are designed specifically for a particular manufacturer's truck.

We do not recommend that shovel weighing devices be tested under this project at this time, because they are all designed for rope shovels only. Both mines participating in the field testing phase use hydraulic shovels, so rope shovel weighing devices will not meet their requirements. Furthermore, there is a trend toward using hydraulic shovels in the mining industry. There are no hydraulic shovel payload monitoring devices currently available.

The selection of a payload measurement system for trucks is made difficult by the fact that most of the systems are truck brand specific, and most mines have a mixed fleet of trucks. The

only system which is not associated with a particular truck manufacturer is the OBDAS system, which has already been tested through another CANMET project. A difficulty is that it may not be effective on all truck frame designs.

We recommend the testing of the Caterpillar Truck Payload Measurement System for the following reasons:

- Both mines participating in the project use Caterpillar trucks.
- It is reasonably representative of such systems and meets the requirements of mine operators.
- The only other logical candidate, the OBDAS system, has already been tested under a separate project. Testing the Caterpillar system provides the opportunity to expand the industry's knowledge.

The Truck Payload Measurement System is primarily used to measure, display, and record the weight of material being hauled by off-highway trucks. This information is useful in monitoring the productivity and activities of trucks in a mining application.

In addition to payload information, several other items are recorded for each cycle by the payload measurement system for later access and use by mine management. A few of these items include idle time, travel time loaded and empty, loading time, and traveling distances loaded and empty. From this data, a number of characteristics of the loading cycle can be determined by the mine management. In order to access this information, the truck payload measurement system provides a serial communications port to the user. The user can connect a compatible device into this port and extract the data.

Production Monitoring, Control and Data Communications

As the structure through which data from these systems will be collected, transmitted, reported and displayed, the Wenco International Production Monitor and Control System (PMCS) is recommended because:

- The software for communications, processing, displaying and reporting is already well developed.
- PMCS has an advanced data radio communications system developed for open pit mines. The protocol was designed to accept information from other sources.

- PMCS is currently being successfully used at the two operating mines participating in the project.

- PMCS is a proven product that is applicable across a wide range of mine sizes and types, so the benefit of the work to the mining industry will be maximized.

Wenco's PMCS is a computerized truck/shovel management system designed to meet a wide range of needs in open pit mines. Production and operating information in real time is sent from equipment in the mine to a base computer, where it is displayed and stored.

The displayed information can be used by production staff to make decisions on equipment allocation as the shift progresses. The data collection process can be unmanned, or manned from time to time to track progress and make changes as required. The computer automatically calculates the dispatch assignment for the truck then sends the instruction to the driver through the data radio link.

The system consists of Mobile Data Terminals (MDT's) in the trucks and shovels, a data radio communications link, and the MONITOR computer which displays and stores the information. Another computer is used for the MANAGEMENT INFORMATION SYSTEM (MIS) for longer term data storage and generation of graphs and reports for management.

Comprehensive Monitoring

Comprehensive monitoring information is required for component management and predictive maintenance. We did not envision studying comprehensive monitoring as part of Phase 1 because of the production-oriented terms of reference of the project. However, comments received from mine operators suggest that comprehensive monitoring should be examined in greater detail.

We recommend that this important area be studied further. A different approach to this area is required, however.

Comprehensive vehicle monitoring does not readily lend itself to integration into the truck/shovel production monitoring system for two major reasons:

1. The end user of the information is in the maintenance group.

2. The data radio system requirements for short-message real time applications is different than for long-message batch data.

Accordingly, this study should be carried on in parallel with the integration components. Rather than delay the continuation of the project as a whole, Phase 2 should proceed on the planned schedule. To advance the comprehensive vehicle monitoring portion of the project to the same point as the rest of the project, we recommend that the "Phase 1 and 2" tasks for comprehensive vehicle monitoring be performed in Phase 2.

5.4 Data Transfer

5.4.1 Overview

It is the objective of the data transfer system to handle all of the data radio needs of the integrated system. It must perform under conditions that include extremes of dust, vibration, powerful electric fields and other interference sources, and in the presence of massive steel structures and terrain that impedes line of sight transmission.

Information from digital devices like computers and mobile data terminals is in binary form (ones and zeros), represented by DC voltage pulses. Radio is an analog medium, so the DC pulses must be converted to a form that can be transmitted. This conversion is accomplished by a modem (a contraction of modulator/demodulator), which converts bits or entire characters into audio frequencies to modulate the radio frequency (RF) carrier. The radio signal is demodulated by the receiving station, and the audio tones are converted back into DC pulses understandable by a computer.

Computer-based truck monitoring and dispatching systems created the first real requirement for mobile data communications in mines. Recently, equipment information systems, mobile equipment location devices, and other electronic devices have either become available or are proposed for open pit mines.

Data from the following components of the operating and management system are being considered for integration through a common data radio system:

1. Mobile Equipment Location System. To be useful, this information is required in real time. A wide range of possible devices can indicate location, including:

   - Navigation equipment which can provide continuous location monitoring. The volume of radio traffic generated from such devices could be extremely high and require a separate radio channel.

- Roadside marker beacons which transmit a location code to passing equipment. The mobile equipment then processes the code and sends a short message to the base computer giving its location and truck identification number.

- Operator input through a mobile data terminal. This is an indirect method of vehicle location which uses the production monitoring information keyed in by the driver. The vehicle location can be inferred from the position in the haul cycle (e.g., Arrive at shovel, Dump, etc.)

2. Dispatching

- This message from the base computer to the trucks can be very brief, containing only a truck ID and the assigned destination. This information is required in real time.

3. Equipment Information System

- Equipment information systems cover a wide range of functions, and provide data that are used by different parts of the mine organization.

- Vehicle health monitoring systems provide two types of data. The first is vital signs, which reports critical conditions such as overheating, overspeed, and oil pressure drop. This information is required in real time to allow someone to act quickly to an emergency situation.

- The second is referred to as comprehensive monitoring, which collects data on the mechanical health of the vehicle over a period of time. This information needs to be reported only infrequently for analysis.

The nature of the data affects the choice of the most appropriate data transfer system for a particular application. Factors to be considered are whether the messages are long or short, the need for the information in real time, and the expected traffic volume. The table below categorizes message types and suggests that two different types of radio systems are appropriate.

Real-time/short messages	Non Real-time/long messages
* production monitoring	* comprehensive vehicle health monitoring
* dispatching	* geotechnical monitoring
* equipment location	
* vital signs monitoring	

In addition to meeting basic performance requirements, the data transmission function must be cost effective. The data radio communications portion of a system cannot, however, be analyzed on a stand alone basis because it is an integral and essential part of dispatching, location monitoring and equipment information systems.

The Canadian government agency which controls the assignment and use of radio frequencies is Communications Canada. Communications Canada policy is to treat radio frequencies as a national resource. Accordingly, they want to maximize their use and could conceivably refuse a licence for a data radio system if they think the use is not critical, or that the end result could be achieved in other ways.

Six key areas are of interest in evaluating a mobile data system are briefly presented below. Each of these is discussed in detail in Appendix VI.

Channel throughput - refers to the number of correct messages that the system can handle per unit of time.

Error control - errors in the data will occur because of multipath interference and external electrical noise pulses. Methods are required to detect these errors and correct them.

Access time - the time required from the time the 'send' or 'transmit' key is pressed to the time the message is successfully received and acknowledged. A reasonable specification for a mine data system is an access time of less than one second.

Vehicles per channel - represents the true measure of the system effectiveness and efficiency. The number of vehicles per channel that a system can handle can be determined only by the particular mine configuration, the nature of the data to be sent, the protocol used, and the specifications of the radio transceiver.

Radio RF power - radio systems that can operate effectively in the mine environment with low power are highly desirable because it minimizes the costs of radio hardware and power supplies that must be provided for every vehicle in the fleet.

5.4.2 Available Technology

Mobile data radio communications systems are not "off-the-shelf" products. Systems are designed using particular combinations of specialized software for the application, computer hardware, radio hardware, terminal hardware and software, and data transfer protocols. Accordingly, it is generally not possible to go to a manufacturer of radio communications equipment and expect to receive a system that will answer all of one's needs.

A detailed review of all types of data communications systems is beyond the scope of this report. The systems discussed were chosen because they have potential applicability or illustrate a particular important aspect of data communications relevant to open pit mines.

Technology provided by the following companies have been examined in this investigation. Please refer to Appendix VI for specifics.

- Advanced Electronic Systems Ltd
- ASW Computer Systems Ltd
- Mobile Data International (MDI)
- Mobiltex Data Ltd

Advanced Electronic Systems Ltd.

AESL produces a comprehensive vehicle monitoring system which collects pressures, temperatures, fluid levels, and analog information on-board the machine. This information is processed and stored on-board. Data transfer to a base computer is accomplished with a data radio system. The data sent to the base computer can be further analyzed and used for reporting.

The AESL literature presents two data radio options, one using an un-modified voice-grade radio operating at 2400 bps, the other using a custom unit operating at 8000 bps. These systems are not, to our knowledge, operating in any open pit mines so their performance capabilities are unknown.

ASW Computer Systems Ltd

ASW is currently working on a project with CANMET to design, develop and test a data radio system. ASW anticipates that the system will be used in on-going open pit mine research activities for CANMET, and be used on mining equipment and for geotechnical monitors.

ASW anticipates that later development might see the system used for such functions as truck location systems, truck dispatch systems and applications to monitor remote field instruments. There are no operating systems and no prototypes are planned until later in the project.

Mobile Data International (MDI)

MDI has been highly successful in the mobile data communications business, with their major markets being taxi and utility vehicle dispatch systems, public safety vehicle data enquiry and reporting, and dispatch and tracking of couriers and their packages.

Their data communications systems could be adapted to the needs of the mining industry, although the company has had no experience at mines. The hardware costs could be over twice the cost of the system currently produced by another supplier, and engineering support for the first installations could run up to $200,000 per site.

Mobiltex Data Ltd

Mobiltex Data Ltd currently manufactures the mobile data terminals for Wenco International's Production Monitor & Control System (PMCS). These terminals are designed to operate either with an internal data radio or can be interfaced to existing voice radios.

The data radio system was specifically designed for the mine environment, and uses a signalling scheme called hexadecimal sequential code (HSC). HSC is well suited for the mining environment because the timing relationships in the protocol makes it virtually immune to burst noise and multipath interference.

5.4.3 Recommendations

Merits of Integration on a Single Channel

In principle, it appears sensible to combine various sources of data into a common data radio channel. Arguments in favour of this are:

- Radio channel use is maximized.
- Duplication of radio hardware and associated maintenance is minimized.

There are, however, some compelling arguments against combining data from various systems. These are:

- Responsibility for equipment operation becomes spread over two or more suppliers, potentially leading to disputes as to who's equipment is responsible for failures
- Channel crowding can result, resulting in the need for additional channels necessary regardless of integration.
- Mixing short/real time messages with long/non-real-time messages may require unsatisfactory compromises in the system design.
- The end-users of the information proposed for integration in the system are different. These groups have different priorities and are often even located in different areas of the mine.

In light of the above, the following is recommended:

- Integrate the real time/short message applications: data for truck dispatching, location monitoring and vital signs monitoring.
- Defer the integration of the non-real-time, long message applications until further study has been done and the applications have developed to the point where there are more field installations. This includes data from comprehensive vehicle health monitoring systems and field monitors such as geotechnical instruments. This information should be restricted to a separate from the short message/real time applications.

The reasons for these recommendations are:

1. It is not clear that there would be a net cost saving to a system purchaser to combine all data through one radio channel.

2. Unlike crowded urban areas where radio channels are at a premium, open pit mines are invariably located in remote areas where Communications Canada is more likely to grant extra radio channels for different applications.

3. Radio channels for dispatching and other real-time requirements may be approaching capacity, so adding higher volume information like vehicle health could result in the need for an additional channel anyway.

4. Equipment vendors may be reluctant to rely on another vendors data radio highway to transmit their data.

5. Radio systems currently being used for truck dispatching operate very satisfactorily and would appear able to meet anticipated needs for future dispatching and also be able to incorporate vital signs monitoring.

The integration of the non-real-time information should be reviewed along as part of the recommended work for equipment monitoring in Phase 2.

The recommended approach to data communications is twofold.

1. Integrate the real time/short message applications.

   We recommend that this be undertaken by Mobiltex Data Ltd. because they already make a successful system in use in the mining industry. It is well suited to short messages, and the information to be integrated can be readily incorporated into the Wenco International PMCS system.

2. Defer integration and development of the non-real-time, long message data transfer systems.

We recommend this because the need for this type of information has not been sufficiently examined under the terms of reference for this project to date. As discussed in the Equipment Information section, we propose to examine this as part of Phase II of the project.

5.5 Location Monitoring

5.5.1 Objectives

It is the objective of the location detection strategy to provide a current view of monitored equipment in relation to a map of the mine, and to provide such location information to the dispatching program as is required for it to perform its work.

In keeping with the preceding statement, the location monitoring function is a subset of the dispatching module. Its performance is not separately quantifiable except by observation of its success, or frequency of failure, to meet the needs of the dispatching programs. User acceptance of the truth of location information presented on a dynamic map of the mine will also be a criterion, indicating user confidence.

5.5.2 Available Technology

There are a large number of automatic vehicle location systems in operation or under development. Most of those that are fully developed are intended for air or marine navigation use. Several, at various stages of development and implementation are intended for automotive use. Those non-mining systems that have been considered for use in the Integrated Truck-shovel Operating and Management System are itemized in the tables contained in Appendix VII. The three that are presently used for monitoring the location of equipment in open pit mines (Charlemagne, Modular, Wenco) all employ some form of proximity detection using low powered radio signals radiated by a marker beacon placed at intersections or other key points.

A number of navigational systems that base their information on radio signals, sensitive altimeters and inertial or doppler devices have been discussed and compared. Existing proven technology has been designed for air and marine applications, with proposed or experimental technology emerging in the automotive world. An assembly of these proven technologies, delivering coordinates periodically to a device similar to a PMCS Mobile Data Terminal for transmission to a central computer, might represent an option for a mine requiring universal, full time location information.

More information and discussion of the features of various systems can be found in Appendix VII hereof.

Alternative means of location identification include satellite based global positioning systems, active ranging radio navigation systems, long wave triangulation systems, dead

reckoning systems, and passive ranging systems using marker beacons.

For the purpose of this project, consideration has been given to:

- a Global Positioning System (Trimble 4000S)
- a number of radio navigation systems typified by Loran
- two microwave radio detection and ranging systems.
- dead reckoning approaches.
- marker beacons and beacon receivers.

In general, satellite based systems are considered too expensive and lacking the ruggedness required for service in surface mining equipment, long wave systems (Loran) lack the accuracy required and are also expensive, radar systems have the required accuracy, but require that equipment remains within line of sight of a single antenna location, are costly and no survivable location can be found for suitable placement of the antenna.

The unusual nature of operating conditions in mining will be a significant impediment to some of the approaches considered. Large masses of steel and powerful electrical fields, as well as magnetic orebody anomalies, will present problems for magnetic devices. Dirt and dust can be expected to foul delicate equipment. Vibration and shock conditions can be brutal.

Of all the approaches considered only one receives user support among the mines and presents a high probability of success in application. Marker beacons (Wenco, Mobiltex) are further discussed in the following recommendations.

5.5.3 Recommendations

The approach recommended for inclusion in the Integrated Truck-shovel Operating and Management System project involves the use of strategically located marker beacons, by the roadside and beacon receivers in truck mounted Mobile Data Terminals to provide location information at intersections and other decision points. This approach is presently used in PMCS at one mine for the purpose of triggering an automatic computer generated dispatch at pit or bench entry points or dump exits.

Within the Integrated Truck-shovel Operating and Management System project, this strategy will be expanded, to the extent that equipment operator intervention is not required to identify

truck location and status information. The following three levels of automation will be demonstrated, using PMCS as a base:

- a PMCS version requiring operator interaction for all functions.
- a version requiring operator entry of exceptions such as delay codes.
- a version not capturing delay data, that is fully automatic as far as the truck driver is concerned.

Software will be developed to interpolate and predict time over routes, and to display mining equipment accurately on a map of the mine. Units failing to reach their next reporting point within a reasonable margin over predicted time will be flagged for staff attention.

5.6 Data Base

5.6.1 Objectives

It is the objective of the selected data base system to store information gathered from the various subsystems of the integrated system, and to provide ready access to that information in a form useable to mine operators.

5.6.2 Available Technology

The following products are offered for sale as relational data base systems. They are considered here as candidates for use in the CANMET Integrated Truck/Shovel Mine Management System. The guidelines for the use of the Data Base with the Management System are set out in the memo LJT to File(CANMET) dated 28 June 1988, included in appendix VIII. The list of products considered is:

Clipper	DB2
dBase III Plus	Emerald Bay
Focus	FoxBase
Informix	Ingres
Oracle	Paradox
Revelation	SQLBase
Sybase	XDB
XQL	

5.6.3 Recommendations

dBase III, manufactured and sold by Ashton-Tate is a widely used, moderately capable data base system. Because it is a very cost effective offering, and because it has a very large acceptance in the computing and business community, it is recommended as the product to be used in the Integrated Truck/Shovel Management System. The criteria and expanded rational for the selection of this product over the others named is presented in Appendix VIII. It is recognized that there are several packages in the market place which are functionally equivalent to dBase III. These include Clipper, and Foxbase 2.1. The recommendation of dBase III is not intended to explicitly exclude these products, but rather, to serve as an indication of the preferred 'type' or 'class' or 'style' of data base product to be used.

6. Phase II Program: Development and Testing

6.1 System Specifications

Following the conceptual design included as Appendix II of this report, and relying on information learned during the development and testing phase, a System specification for the Integrated Truck-shovel Operating and Management System will be developed. This is a necessary precondition to establish requirements for budget purposes, for Phase III integration work.

6.2 Integration Components

6.2.1 Simulation

Statement of work

The work involves two companies, Wenco and Ad Opt, each making appropriate advances to their proprietary material.

With overall coordination being provided by Wenco, Ad Opt staff will convert the present simulation programs to run in the microcomputer environment, and develop ways to use real time data provided by PMCS where this is appropriate. Wenco will develop the required interface technology and revise its Monitor program to provide the output required.

Both companies will participate in lab and field testing, in conjunction with the testing of the similarly modified Ad Opt dispatching program described in the following section.

Methodology

The following tasks are required to integrate Ad Opt's simulation logic into PMCS and test it:

- A meeting between Wenco and Ad Opt personnel to design the interface between the two programs. Interfacing must address the following issues:
  - data structures,
  - file structures,
  - operating systems,

- LAN protocols,

- Language selection, etc.

- The Simulation logic is to be converted so that it runs on a micro-computer. This will be done by Ad Opt personnel.

- The mine's PMCS equipment and location data will be made available to the Simulation program. If the file format is incompatible with the Ad Opt system, Wenco will write a conversion utility.

- Wenco will develop a customized PMCS shell utility that will run the simulation program. This shell utility will prompt the user for all the required interactive input information and convert it to a form that can be read by the Simulation program.

- The simulation program and its PMCS interface will be unit tested in the lab.

- A follow up meeting between Wenco and Ad Opt will be held to evaluate the unit test. Program adjustments will be planned. Field installation will be planned, especially the evaluation criteria.

- Program adjustments will be made by Wenco and Ad Opt if required.

- The program will be installed and run in a mine. At first it will be run in parallel with the manual procedures. Selected baseline data will be collected for evaluation purposes.

- The simulated shift plans will be used by the mining operation. The system will be evaluated by comparing the evaluation data from before system installation with the post installation data.

6.2.2 Dispatching

Statement of work

The dispatching algorithms have already been developed by Wenco and Ad Opt. Wenco's waiting time minimization algorithm is installed in PMCS so no further work is required for it. The primary task is to adapt Ad Opt's algorithm so that it can be run from within PMCS.

In order to accomplish this, the Ad Opt's dispatch algorithm must be:

- converted from a mini-computer to a micro-computer format,
- interfaced with the simulation program that generates an optimal shift plan,
- interfaced with PMCS,
- unit tested in the lab, and
- unit tested in the field.

Methodology

The following tasks are required to integrate Ad Opt's dispatch logic into PMCS and test it:

- A meeting between Wenco and Ad Opt personnel to design the interface between the two programs. Interfacing must address the following issues:
  - data structures,
  - file structures,
  - operating systems,
  - inter-process communications techniques,
  - LAN protocols,
  - Language selection, etc.
- Wenco will modify its PMCS MONITOR program so that it manages the inter-process communication between it and the Dispatch program.
- If required, Wenco will modify its PMCS MONITOR program so that it will generate the dispatch program with the real-time data it requires.
- The Dispatch logic is to be converted so that it runs on a micro-computer. This will be done by Ad Opt personnel.
- An interface between the Simulation and Dispatching program will be written. This will be done by Ad Opt personnel.

- The mine's PMCS equipment and location data will be made available to the Dispatch program. If the file format is incompatible with the Ad Opt system, Wenco will write a conversion utility.

- Wenco will develop a customized PMCS shell utility that will run the Dispatch program. This shell utility will prompt the user for all the required interactive input information and convert it to a form that can be read by the Dispatch program.

- The Dispatch program and its PMCS interface will be unit tested in the lab.

- A follow up meeting between Wenco and Ad Opt will be held to evaluate the unit test. Program adjustments will be planned. Field installation will be planned, especially the evaluation criteria.

- Program adjustments will be made by Wenco and Ad Opt if required.

- The program will be installed and run in a mine. At first it will be run in parallel with the existing system. Selected baseline data will be collected for evaluation purposes.

- The dispatch algorithm will be used by the mining operation. The system will be evaluated by comparing the evaluation data from before system installation with the post installation data.

6.2.3 Equipment Information

During Phase II it is proposed to further evaluate the feasibility of including equipment health monitoring in the Integrated Truck-shovel Operating and Management System project.

Statement of work

Following the recommendations in sections 5 and 6 of this report a study will be made of the characteristics of data required for the support of maintenance requirements, their application in real time and the appropriate means of downloading data from this application.

6.2.4 Data Transfer

The recommended course of action depends upon present, effective data communications technology as applied in Wenco's PMCS. The modification and programming work described in the preceding subsection, involving the Mobile Data Terminals and the Monitor computer, is included in section 5 Equipment information.

6.2.5 Location Monitoring

The Mobiltex marker beacons as presently designed, meet the needs of the Integrated Truck-shovel Operating and Management System. Modification to the Mobile Data Terminal is required, and additional software must be developed for both the on board equipment and the central computer.

Statement of work

It is an objective in this Phase to develop the necessary hardware and software to accurately monitor equipment as it moves about the mine; to present the location information so captured on a dynamic map of the mine; and to use the data to guide a dispatching program, without truck driver intervention.

The work will be based on the present Mobiltex marker beacon and beacon receiver - Mobile Data Terminal (MCRB). Memory will be added to the MCRB to accommodate the additional logic required to further distinguish activities in relation to beacons, for reduction to status information.

Software is to be developed for both the MCRB and for the PMCS "Monitor" program, to accept the beacon location information and calculate truck status therefrom. Additional software is to be developed to display equipment position on a dynamic map of the mine, determining relative position between beacon locations by logically sectioning the known average travel time for each truck fleet and direction on each route.

The completed modules will be installed in a test mine, tested, corrected or fine tuned as necessary, then run for a short evaluation period.

Methodology

The following tasks will be undertaken in this Phase:

- Select the cooperating mine.

- Study and record the road network, and jointly with the mine operator specify the number and location of beacons, sufficient to completely serve at least one route and the number of trucks to take part in the test.

- Design and code modifications to the Mobile Data Terminal (Mobiltex)

- Design and code PMCS software to interpret and effectively use the data in place of (or in addition to) the present status signals.

- Install beacons and modified Mobile Data Terminals.

- Attend at the mine to monitor the results of testing for 10 consecutive days

- Revise system software as required.

- Testing and acceptance.

- Gather operating results from trucks using the new technology and others on the same routes using present technology, for comparison.

- Statistical analysis of those results.

6.2.6 Data Base

This section sets out the anticipated activities required to develop & test the data base interface to the Integrated Truck/Shovel Management System.

Statement of Work

- Finalize Selection of Data Base Software. Determine whether Ashton-Tate's dBase III Plus is the best solution at the time of implementation, or whether the anticipated dBase IV should be used. Additionally, the compatible product, FoxBase, should be considered.

- Order Software

- Install Software

- Design data base. Quantify data base requirements, sizes, etc. and create formal definitions for the data structures to be used.

- Implement the data base design - create schemas, DDL's, file definitions, etc.

- Design the transaction processor interface to the remainder of the Integrated Truck/Shovel Management System.

- Implement the transaction processor. Perform the coding, unit testing, etc. required to create a functioning transaction processor, or equivalent facility for use in a network environment.

- Perform testing to establish that the required functionality has been implemented, and that the data base does indeed provide a useful ad hoc reporting facility for mine operators. Establish maximum rate and size attributes for the system as implemented.

- Documentation. Produce and publish appropriate functional description and user documentation for the data base facility.

Methodology

The implementation of the data base will be accomplished by the following methodology:

- Review Selection of Data Base Software
- Design T/S Management Data Base
- Implement Data Structure
- Design Transaction Processor
- Implement Transaction Processor
- Perform Integration Testing
- Perform Volume & Timing Testing

6.3 Involvement of the Mines

Both of the participating mines (Suncor and Greenhills) support the total project in principle. They have agreed to specific involvement as required for Phase I. Their continued involvement for the remaining three phases is subject to their review of the Phase I results. To assist the mines in assessing the project the following information is presented.

When considering the field testing of the various modules it was assumed for scheduling and budgeting purposes that the vehicle vital signs and the payload monitoring testing would be conducted at Suncor. The location monitoring, and the simulation and dispatch would be tested at Greenhills. The database module

can be implemented at either or both, but the present intention is to place it at Greenhills for the Phase II testing. These selections may be adjusted in consultation with the mines at a time closer to the start of the tests. In making these choices, we have considered that the relatively more complex dispatching problem at Greenhills will provide a more thorough test environment for the modules involving the dispatch function.

For Phase II it is intended that appropriate equipment will be mounted on three trucks at each mine, so as to provide a continuous two truck minimum test after allowance for equipment availability. Naturally, every effort will be made to perform the installation work with the minimum interference with equipment availability. Once installation is complete, Wenco staff will attend at site for a one month period to gather test results, modify the system as necessary, and complete acceptance testing.

The participating mines will benefit from this stage from:

- The opportunity to evaluate new technology at work in their own mining environment at no direct cost.
- The opportunity to expose staff to a range of high technology applications.
- Presence of Wenco staff on site for a month will provide an opportunity for mine staff to maximize the understanding and effectiveness of their use of PMCS.

7. Phase III Program: Integration and Testing

7.1 Statement of Work

Hardware and software standards

This section sets out the recommendations for the integration of the individual components of the CANMET Integrated Truck/Shovel Management System into a cohesive entity.

The individual components of the system are to be implemented on IBM PC/XT or IBM PC/AT compatible computers as required by sub-application size and speed. Individual computers are to be connected to a Local Area Network to provide for the interchange of essential data between sub-applications, and to provide for backup, remote access, etc. Where it will provide an economic advantage, sub-applications will take advantage of the Data Base interface for storing and exchanging data. The Local Area Network will have sufficient speed and capability to allow the sub-applications to interact effectively. It is recommended that the speed of the network be at least 2 Megabits per Second (nominal), and that it support record and file locking for shared data access. Additionally, there should be an access control facility to prevent the accidental alteration or deletion of data by unauthorized individuals.

Statement of Work

Final Integration of the Truck/Shovel Management System will be accomplished as follows:

- Select a suitable mine site for the Integration test
- Plan integration testing with mine personnel
- Design data exchange interfaces
- Modify system components to accept interface
- Finalize selection of LAN technology
- Order LAN Hardware & Software
- Install LAN at lab facility
- test individual modules in presence of LAN
- Test (as far as possible) entire system at lab
- Install Integrated system components at test mine
- Bring up integrated system
- operate integrated system for required time.

7.2 Involvement of the Mines

No determination has been made regarding the selection of the cooperating mine for the Phase III and IV work, although these will necessarily be one and the same mine. The mine operators will be in a much better position to express their desires in this matter after completion of the Phase II testing.

Phase III will involve the installation of a complete set of mobile hardware on three trucks, presuming that the three trucks selected will be the same three as used in Phase II at one of the mines. A test period of one month is envisaged in this Phase, similar to the tests performed in the second phase, but complicated by the wider range of system components running simultaneously.

Benefits to the participating mine are similar to those mentioned in discussing the Phase II testing procedures.

8. Phase IV Program: Demonstration and Evaluation

8.1 Statement of Work

During the fourth phase, it is intended to operate the completed Integrated Truck Shovel Management System for a one year period, to gather data for accurate assessment of the benefits accruing to the operator, and to demonstrate the system to other mine operators and researchers.

Wenco staff will be present at the mine site five days per week during this period, both to support the operation of the system and to gather and analyze results.

8.2 Involvement of the Mines

Since equipment installed in Phase III will be the basis of the demonstration and evaluation work, no further direct impact on the mine equipment is expected, with the exception of possible down time which may be caused by the system itself. This is not expected to be a significant factor. The selected mine will be asked to contribute suitable working space for collaborating Wenco staff, and to whatever extent it is practical, to cooperate in meeting the maintenance and information needs of the system under demonstration.

The cooperating mine will be expected to provide reasonable access to others for demonstration purposes, without disruption to their normal operation of the mine.

Benefits to the mine participating in this phase include:

- An enhanced opportunity to evaluate new technology in their own operating conditions.
- On site PMCS support for a full year.
- A staff experience broadening and training opportunity, related to the Wenco staff presence and their brief to both maximize and measure the results of the test program.

9. Costs and Benefits

A detailed Phase II budget, cost estimates for Phases III and IV, and basis of payment discussion are presented in a confidential addendum to this report. In this section, summary project cost by task and phase is presented, as well as a discussion of the anticipated benefits arising out of the use of the Integrated Truck Shovel Management System. Finally, costs and benefits for a typical installation are presented. For this purpose, costs are based on a fictional 25 truck five shovel mine, and benefits are based on the technical literature.

9.1 Phase II Budget

The following item costs can be related directly to the project schedules enclosed as Appendix IX.

- Project planning, intellectual property	745,400
- Vehicle health monitoring study	60,260
- Location monitoring	76,898
- Data base	75,300
- System specification	63,705
- Vital signs monitoring	44,931
- Simulation and Dispatch	85,865
- Payload monitoring	78,731
- Prototype testing at Suncor	91,609
- Prototype testing at Greenhills	100,699
- Phase II Review	20,120
Phase II total:	$1,443,518

9.2 Project Cost Estimates

At this time, actual costs for Phase I are known; Phase II costs are budgeted as set out above; Phases III and IV are estimated. Total projected costs are as follows:

Phase I	67,454	Complete
Phase II	1,443,518	November '88 - April '89
Phase III	234,900	April '89 - October '89
Phase IV	1,216,294	October '89 - November '90
Total project:	$2,962,166	

The estimated cost for including comprehensive vehicle monitoring in the project is difficult to establish at this time. The following is a rough preliminary estimate which will be refined as the project proceeds. The following estimates are included in the above.

1. User survey	$20,000
2. Further review of available technology	10,000
3. Conceptual system design	10,000
4. Budgets, subcontractor selection, and reports	20,000
Total Preliminary Estimate	$60,000

9.3 Projected Benefits

Mining equipment is becoming larger and much more expensive. People are costly too, and changes in working rules tend to reduce, rather than enhance productivity. The Integrated Truck Shovel Management System provides benefits directly related to the high capital cost of mining equipment, and the efficiency of labour.

- Achieves the maximum production per operating hour, consistent with mining requirements.
- Supports the mine planning function with accurate data, resulting in plans of inherently greater efficiency.
- Permits the accurate evaluation of proposed equipment purchases.

- Processing plant efficiency and cost are enhanced by the accurate control of feedstock blend.

- Positive feedback is provided for people through accurate real time information concerning the results that are being achieved.

- More effective utilization of mining equipment to achieve planned results on a shift by shift basis.

- Lower capital equipment and manpower requirements over the long term, resulting from improved productivity.

- Improved management control, through the provision of accurate, timely information.

- Reduced cost through the elimination of paperwork.

Certain benefits accrue directly from individual modules of the Integrated Truck Shovel Management System. Depending upon the individual mine operators needs, certain modules may be selected to the exclusion of others.

Payload monitoring

- Maximum load consistent with safety.

- Minimum tire and suspension maintenance cost.

- Blend control accurate to the lowest measurable unit.

Vital signs monitoring

- Protection of for costly engines and other equipment left idling unmanned.

- Protection of manned equipment through a controlled shutdown procedure.

- Offers maintenance staff a control over safety shutdown set points.

Simulation

- Fewer shovel moves will be required.

- Shift planning will be supported by quantitative information, removing some human biases.

Dispatch

- Optimized use of mine equipment for minimum unit production cost.
- Accurate real time mine planning data.
- Alternative shift plans readily at hand to meet changing equipment availability and mine conditions.
- Sophisticated 'what if' analysis capability. Validate or predict future equipment requirements.
- Closes the communications gap between mine planning and mine operations, for more effective pro-active planning.

Location monitoring

- Permits the full automation of the truck dispatching function.

Database module

- Provides a central storage for all mine operations information, to serve planning, engineering, maintenance and operations departments.
- Permits custom information retrieval to suit individual requirements.
- Automates data acquisition for corporate information processing needs.
- Simplifies the archiving of mining records.

9.4 Users' costs & benefits

Presented in this section is a selection of material intended to provide the reader with sufficient cost and benefit information to perform a preliminary evaluation of all or any component of the Integrated Truck and Shovel Management System, for use in a particular mine.

The reader is cautioned that costs vary significantly with the specific needs and requirements arising out of each mine's operating conditions. Minimum and maximum cost estimates are presented. While these costs are calculated in respect of a "typical" 25 truck mine, one can not assume that a 50 truck mine

would cost twice as much. In areas where this relationship is most significant, a footnote provides additional information. In each case, installation, commissioning and operator training are assumed. That is, the costs presented are based on a turn-key implementation. These costs represent a typical installation in Canada.

Benefits claimed are extracted from previously published studies. In this respect it should be noted that there is a significant overlap and these benefits can not reasonably be expected to accrue cumulatively. An attempt has been made to isolate the claimed benefit related specifically to the component under discussion, and where this has not been possible additional cautions have been added in footnote. Available benefits are heavily dependent upon the present efficiency of the mine, as well as such things as the balance between trucks and shovels.

For the purpose of evaluating benefits, empirical data from mines of a similar size to our theoretical 25 truck mine have been examined and a number of average costs and productivity factors produced. The following calculations of benefit rest on empirical (1985) data summarized as follows:

Equipment	Cost/GOH	BCM/GOH
Demag 241	$275	491
P & H 2100	$223	393
P & H 2800	$334	692
Terex 170T	$128(tires $12.5)	159
	$144(tires $13)	138
Euclid 100T	$124(tires $7)	112

For our purposes average empirical data based on above is:

LOADING EQUIPMENT:	$0.52/BCM	$277/GOH	500 BCM/GOH
HAULING EQUIPMENT:	$0.97/BCM	$132/GOH	135 BCM/GOH
Tires:	$13/GOH (170T)	$7/GOH (100T)	incl. in above total
Fuel:	$25/GOH (170T)	$15/GOH (100T)	incl. in above total

Real time mine monitor, data communications

Includes a real time mine monitoring capability and the data communications required by all other components. This is considered as the foundation or pre-condition for the use of other components of the Integrated Truck and Shovel Mine Management System although some of these components, notably payload and vital signs monitoring, are capable of delivering a portion of their benefits without real time data communications.

Costs	Minimum	Maximum
Typical 25 truck mine(1)	$300,000	450,000

Benefits

Benefits accrue through real time monitoring of the mine and the identification of opportunities to convert waiting and delay times into productive or standby times, according to the needs of the mine. The ability to directly observe and measure the effects of changes in operating strategies permits significant opportunities for conscientious management.

Most importantly, regardless of present efficiency, real time monitoring of the mine provides the opportunity to observe and measure actual performance in suspect areas, and to measure the results of corrective action taken. Also measurable are the results of strategic changes, such as the introduction of automatic truck dispatching.

The following effects have been reported:

- Identification and control of avoidable truck delays of 20 minutes per truck per shift. The equivalent of 1/36th of a truck x 25, free of both capital and operating costs

- Significant improvement in truck shovel balance through accurate knowledge of waiting times in each setup. Reductions in truck and/or shovel waiting times vary immensely, depending upon prior efficiency.

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(1) 50 truck mine: $420,000 - 600,000

Example Cost Approach to cost benefit calculation

Payback calculation for mine monitor benefit of 20 min per truck per shift. Assuming no additional personnel hired to operate monitoring system.

TimexNo.shifts/dayxNo.trucksxAvailxDays/yearxCost/GOH = .33x2x25x0.8x351x132= $615,000prox./year for 25 truck fleet.

The above is maximum since it assumes all delay time is converted into GOH. A reasonable minimum is that 70% of delay savings goes to GOH ie. a savings of $430,000/year.

Worst case Payback = maximum cost and minimum savings = $450,000 and $430,000 = 1 year approx.

Best case Payback = minimum cost and maximum savings = $300,000 and $615,000 = 6 months approx.

Example Productivity Approach payback for above.

TimexNo.shifts/dayxNo.trucksxAvailxDays/yearxProductivity = .33x2x25x0.8x351x135 = 630,000 BCM/year approx.

One truck production per year = 24x.8x351x135 = 910,000 BCM/year

Maximum payback = savings of 0.7 of a truck

Minimum payback = savings of 0.5 of a truck

Automatic truck dispatching

Costs

	Minimum	Maximum
Typical 25 truck mine	$50,000	100,000

Benefits

The following effects have been reported:

- Reduction of 10% in shovel waiting time, coupled with a corresponding increase in shovel standby time, with production unchanged. Cost reduction of $1,000,000 per year.

- Production increase of 12%; truck waiting time decrease of 72%; shovel waiting time decrease of 19%.(2)

Equipment information - payload control

Costs	Minimum	Maximum
Typical 25 truck mine	$250,000	350,000

Benefits

Benefits arise out of maximizing the payload carried during each cycle, while protecting trucks and tires from damage resulting from accidental overload. These benefits can largely be realized without real time data communications. Results reported include:

- increase in the average load per cycle of 3.6%
- cost saving of $0.02 per BCM

Two potential payback areas, based on the assumption that most mines either (1) underload the trucks on the average by 5% or they (2) overload the trucks by 10%. Mines more likely to overload than underload

1. Savings by increased productivity. (100T truck):

For 25 unit fleet (assume 75% GOH to Scheduled hours)
GOH/year = 25x.75 24x351 = 158,000 approx.

Loads/year = 158,000x135/35 = 609,000 approx (assume 35 BCM/Load)

At 5% extra = 30,000 loads per year or 1,000,000 BCM

This is equivalent to savings of 0.97x1,000,000 = $970,000/year

Payback Period: Worst = 7 months Best = 3 months

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(2) Some portion of this gain would be realizable with real time monitoring only.

2. Savings by Tire costs:

Assume tire life is directly proportional to overloading

Total GOH/year = 158,000 for fleet

Tire Cost = 10x158,000 = $1,580,000/year

Savings at 10% reduction = $158,000/year. This is minimum savings since no consideration given to savings on truck frame and suspension

Payback Period : Worst = 16 months Best = 15 Months

Equipment information - vital signs monitoring

Costs	Minimum	Maximum
Typical 25 truck mine	$115,000	175,000

Benefits

Benefits arise through the automatic protection of expensive engines, which can be achieved without real time monitoring, since automatic shutdown will offer adequate protection in many cases. Real time annunciation of shut-down action can provide significant extra protection when unattended equipment is shut down, especially in severe winter conditions. Reported benefits:

- One user reports the safe shut-down of two engines suffering coolant loss, without engine damage. This is clearly mine specific. How many lost engines would be saved each year, and at what cost?

Payback calculation

Assume our 25 truck mine runs 100 ton trucks and suffers six catastrophic engine failures per year.

6 engines at an average rebuild cost of $65,000 and 1/3 of these preventable= (6x65,000)/3= 130,000

This is a minimum savings since most catastrophic engine failures are preventable. For maximum assume 2/3 are saved.

Payback Period : Worst = 16 months Best = 5 Months

Location monitoring

Costs	Minimum	Maximum
Typical 25 truck mine	$25,000	100,000

Benefits

No separate quantification of benefit is claimed for location monitoring. Benefits accrue to operators who prefer to fully automate the truck dispatching function, requiring no input from equipment operators. Marginal improvement in automatic truck dispatching efficiency can also be expected.

Data base

Costs	Minimum	Maximum
Typical 25 truck mine	$45,000	50,000(3)

Benefits

Benefits arise through provision of a central storage for all mine operations information. Permits information retrieval to suit individual requirements of a wide variety of users and automates data acquisition for corporate information processing needs.

- Quantification of benefit is mine specific, depending upon the amount of time now spent in the acquisition and handling of data, and the extent to which "multiple versions of the truth" cause present inefficiencies.

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(3) Not significantly affected by mine size.

9.5 Project schedules

Suggested project schedules are appended herewith as Appendix IX. These schedules are prepared assuming immediate sources of funding are identified and work can commence on the second Phase immediately. Without provision for slack time, completion is envisioned for September of 1990.

Included are both a Task Gantt chart and a Critical Path network chart depicting the project as a whole. These reflect four Phases including the investigative Phase I of which this report is the conclusion. In these charts, the Phase II development tasks are represented as single items. These development tasks are represented in further detail on sub-task Gantt charts.

APPENDIX I

USER REQUIREMENTS

USER REQUIREMENTS

for an integrated surface mine management system

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1 INTRODUCTION

This is the definition of user requirements for a surface mine management system, broadly described in the STATEMENT OF WORK appended to Canmet Contract Number 23440-7-9148. That statement of work is presented for comparison to the requirements as set out herein.

Secondly, the views of mine operators are presented in a capsule form, as background for the recommendations implicit in the requirements. Certain assumptions are set out and existing technology is identified, as appropriate.

Finally, each of the elements of the system is discussed in some detail and in a form that will spell out the needs and expectations of mine operators. This is an iterative process. It is anticipated that changes and additional detail will be provided at each stage of review by participating mines and Canmet. Upon completion, it is expected that system functionality and user interface requirements will be clearly spelled out from the users' point of view, for the guidance of Canmet in defining the future direction of the program.

This document will then form the basis for a preliminary system specification.

2 SURVEY METHODOLOGY

This work was undertaken for the purpose of ensuring that proposed subsequent work in the development, testing and evaluation of an integrated truck shovel management system would be relevant to mine operators needs, and as a necessary step in securing cooperation from mine operators in the testing and evaluation phases.

The survey design selected had to deal with several factors. There is never a single, standard correct method of carrying out marketing research, but the circumstances in this project clearly pointed to the use of exploratory research methods rather than descriptive study techniques. The use of exploratory research techniques was selected because it:

- has emphasis on discovery of ideas and insights
- is generally appropriate to any problem about which little research information is available
- is characterized by flexibility

The use of a descriptive study was rejected for several reasons. Descriptive studies are concerned with determining the frequency with which something occurs or the relationship between two variables. They are used when the purpose is to describe characteristics of certain groups (e.g.: demographic information), to estimate the proportion of people in a specified population who behave in a certain way, or to make specific predictions. A good descriptive study presupposes much prior knowledge about the phenomenon being studied, and it rests on one or more specific hypotheses.

Where a descriptive study is considered rigid, an exploratory study is characterized by its flexibility.

It is important to understand what can and cannot be accomplished in exploratory surveys. To understand the limitations requires an understanding the individual being interviewed and the environment he operates in. In this regard, some of the key factors that should be considered are:

1 The persons to be interviewed often had an incomplete knowledge of the technology and how it could help them.

2 Mine personnel had uncertain knowledge of the cost/benefit relationship of some of the new technology available.

3 As with any attitude/opinion survey, there were personal biases which have to be considered. These biases could be the result of senior management attitude toward technical innovation, their own attitude toward technology formed by good or bad prior experiences with new technology, and how the technical innovation affected his particular group, whether it be production, maintenance or engineering.

The specific survey methodology used is what is generally referred to as an unstructured, undisguised questionnaire. This consisted in meeting with the mine personnel to obtain attitudes and opinions through open ended responses. The survey also served to identify the degree of awareness and knowledge of the subject.

Secondary sources from literature searches were used to gather background information on the availability of and prior experience with some of the technology.

One of the major limitations of this type of survey is that the results are not necessarily representative of what would be found in the general population. As pointed out elsewhere in this section, there could be widely varying opinions even within the same organization. The sample selection process

was not based on a rigid, random selection process, but rather on the constraints imposed by time, geographical considerations, and economy. Most weight has been given to the views expressed at the two participating mines.

In the analysis and interpretation of data, it must be borne in mind that the results are an amalgam of opinions and cannot be used for performing statistical tests.

The observations and conclusions reported herein are a reflection of the opinions expressed by mining engineering and operations staff at 11 mines (See Appendix "A") interviewed in the process of the work. Very few clear conclusions of consensus could be drawn, even among various staff members at a single mine. Interviews were informal, with the interviewer leading group discussion to questions of desirability of various components of the integrated management system, and if desirable, of features or functions most desired. The variety of opinion usually produced lively debate, from which these conclusions are drawn.

At each mine, an attempt was made to rank the proposed system components in terms of desirability as seen by staff at this site. The results of that ranking are reported in section 5 CONCLUSIONS.

3 BACKGROUND

3.1 Canmet Statement of Work

The statement of work provided by Canmet (Appendix A to the contract) sets out a description of six subsystems or modules that are to be individually developed and tested, then integrated into one cohesive whole and demonstrated. Each of the modules and the integrated system are to be evaluated in operating mines. Briefly, the requirements are:

3.1.1 Computer simulation program

This program is intended for short to medium term production scheduling and must continually accept and process on-site generated data (i.e., the program will use actual recent mine site data to predict equipment performances).

This program is expected to be developed in several modules that may be used independently. The program will accept real time data generated and collected by various mine site equipment and other information systems and drive the dispatching program.

3.1.2 Dispatching program

This program must dispatch trucks in real time in accordance with a variety of mine site policies.

It is proposed that the dispatching system be set up at the beginning of each shift, monitor truck/shovel performance in relation to this basic set-up, and reassign in keeping with specified mine site requirements. This system must allow for user interaction at anytime, and provide trend information as specified by the user.

3.1.3 Equipment information system

This system, with appropriate software, is expected to monitor relevant operating, maintenance and equipment performance data, and feed this data for further processing in the simulation and dispatching programs. Types of data covered by this information system are expected to be defined by the producing mining companies.

3.1.4 Data transfer system

A radio based two way communications system that can send monitored information to a central computer for processing, and relay dispatch decisions, as well as, provide voice communication, is an example of such a data transmission system. The system must provide temporary on-line storage of data for "on-demand" transmission and further processing and data transmission accuracy checking.

3.1.5 Mobile equipment location devices

This component will locate and continuously update equipment location using satellite or terrestrial based facilities.

This automatic vehicle location system is defined as an assembly of technologies and equipment that permits centralized and automatic detection and display of the position and movement of equipment through an area. The results of this system component will be integrated into the simulation program that drives the dispatching module. Other uses of the vehicle location system may be defined by the user.

3.1.6 Data base system

This component is the heart of the system. Format and storage approach must facilitate effective access to the data for a variety of purposes not limited to those included in this technology demonstration program.

3.1.7 Summary

In essence the computer simulation program will take equipment information and location system outputs relayed by the data transmission system, conduct simulations, apply the logic of the dispatch program and inform equipment operators of dispatch decisions.

The central computing facility may also subject the collected data to other analyses to provide operating, management and maintenance information, but those subjects are beyond the scope of this project. The data base system must however recognize and be responsive to future incremental and new uses.

3.2 Evaluation

The original Request for Proposal envisioned the spending of equal sums on each of five elements of an integrated surface mine management and information system. Mine operators and owners of technology alike expressed concern about this approach due to the disparity between the states of the art presently existing in each field, and questions regarding whether the results would be commercially valuable. That is, would the mines benefit by their efforts through the availability of improved techniques that would be cost effective and justifiable?

The primary purposes of the Phase I project, of which these requirements

form a part, is to determine:

- Which among these five elements are supported by needs expressed by mine operators?

- What technology exists now in each field and which of several options will best meet the overall project objectives?

- What will it cost to assemble (or develop) the technology to the point of practical demonstration, given the above?

This document attempts to answer, or lead toward the answer to the first of these questions.

4 MINE OPERATOR VIEWS

In this section we discuss each of the modules with respect to both functionality and desirability from our understanding of the needs and wishes of the various mine operators who have been interviewed. This section is intended to be a descriptive distillation of opinions that will guide the setting out of requirements in subsequent sections.

4.1 The Integrated System

It is recognized that the relationships between the modules described are not absolute. As investigation of available technology proceeds, as the perceived needs of the mine operators become more clear, and as the costs and benefits of options are discovered or disclosed, it is expected that subsystems will be unequally weighted in terms of their desirability and perhaps their development or implementation and testing cost. It is also expected that some items described may operate independent of others more effectively than as integrated modules of a single entity.

The integrated system is to provide an unprecedented degree of information and control for the ultimate purpose of optimizing mining operations. Each component must contribute to the achievement of this broad objective to succeed to the implementation phase.

It is intended that the Data Communications module will deliver information provided by the Vehicle Monitoring system and the Location Monitoring system to feed the Simulation system. The information gathered and generated by all three of these will contribute to the effective decision making processes of the Dispatching system, which will relay its instructions to equipment through the same Data Communications system. All information will be stored in the Data Base module which is to provide ready access for analysis, management reporting and unforeseen purposes.

While integration is a valid objective, mine operators stress that functional modularity is of critical importance. They require that each module be capable of effective stand alone use to ensure that only the desired features must be bought. Economy and minimum complexity might require that features not seen as useful or cost effective in an individual case need not be bought or used.

4.2 Simulation

This program will be capable of using data about equipment performance, mineral qualities, and operating results gathered from operating equipment, together with information about operating requirements to fulfill several useful functions. It will:

- Provide a selection of workable equipment allocation plans that will meet the objectives of the current shift.

- Provide a set of guidance rules for the dispatching program (see below) to ensure that the desired shift results are achieved.

- Provide the capability of planning in the short to medium range, both to improve the mining results achieved and to explore alternatives through "What if" analysis.

- Be sufficiently accurate to offer a firm basis for justification of capital expenditures.

4.3 Dispatching

This program must dispatch trucks in accordance with mine operating policies. Using the empirical data collected from the mine in real time and guidance from the simulation model described above this program will automatically dispatch trucks to meet mineral blend requirements and, within the con-

straints imposed by blend and other specific needs, will maximize equipment productivity. It will be fail safe in several levels:

- The loss of a loading unit during the shift will not disrupt the blend, or if it must do so the dispatcher will be so advised.

- The failure of the dispatching computer to access the dispatch logic will cause a fall back to minimum waiting time logic, warning the operator of loss of blend control.

- Failure of the dispatching computer or the communications link will leave an apparent "Keep on doing what you've been doing," instruction on truckers' mobile data terminals. Operator alert if possible.

4.4 Equipment information

This system is expected to monitor operating, maintenance and equipment performance data to serve the twofold purpose of providing maintenance staff with valuable data upon which to base their efforts, and feeding actual performance data to the simulation and dispatching functions. There is a demand for payload weighing ability, both to control loading to the rated limit and for accurate production reporting. This capability should provide shovel operator guidance while the truck is being loaded.

Several kinds of systems, each with different characteristics, are identified below and each has its supporters in the mining community.

- On-board monitors check pressures, fluid levels and temperatures, warning the operator of any abnormality. May or may not automatically shut the engine down in threatening conditions. There is a significant desire for this function, with 50% of those expressing interest also suggesting downloading information by radio for use

either as emergency control or simply for convenience of data capture. (Ropec and others)

- Monitor and record payload and detailed operating cycle time information such as speed, forward / reverse, dump activated, etc. in addition to physical conditions mentioned above. provides payload guidance to shovel operator. Few proponents, primarily because of lack of confidence in payload measuring devices, but this approach can provide the truck status information needed to support fully automatic, driver independent dispatching. Those interested usually request radio downloading. (Obdas)

- Shovel based payload control systems provide payload control and accurate measure of loading times. Interesting to most operators, and operating at several mines contacted. Payload control from the shovel is less costly and less damage prone than truck weighing. Thought to be less accurate, too. Provides no information except payload, extended to include production reporting summaries. (BEpal)

- There is a considerable desire for a tire control system, which may or may not be an appropriate part of this section. Functions are to record tire life history as a means to cost reduction (Warranties, road maintenance equipment justification) and ton mile per hour calculation (Warranties, operational guidance for tire life extension).

4.5 Data transfer

Described as a radio based two way communications system that can send monitored information to a central computer for processing, and to relay dispatch decisions as well as to provide voice communications. The system is to provide temporary on-line storage of data for on-demand transmission and further processing and data transmission accuracy checking. Each component of

this system presently exists separately, hence the requirement would be to combine these functions in a common radio unit.

Traffic to be carried over this radio system includes voice, monitored health and cycle time data, location information and dispatch instructions.

- Voice radio technology is advanced and widely used.

- Data transmission by radio is available, and used in such systems as PMCS, BEpal and Obdas.

Users question whether there is value in combining these technologies, given that the sources of input and the points of use of the output are separate. They ask why we would complicate and further crowd communications channels by combining all functions for radio transmission, only to divide them into their former parts for processing, on receipt.

4.6 Location devices

This component will locate and update the computer with location information. The results of this system component will guide the dispatching module.

Mine operators indicate an interest in location monitoring to the extent it is useful in the automatic truck dispatching function. PMCS uses a roadside beacon to identify trucks passing dispatch points. Quebec Cartier (QCM) uses similar devices to locate trucks at intersections, loading points and dumps.

None of the mine operators interviewed indicated an interest in more precise information. No mine support has been offered for the development and test of more sophisticated methods such as inertial guidance systems.

4.7 Data base

An organized approach to the storage and retrieval of data amassed by the system to meet a variety of needs, not limited to purposes envisioned within this system. Accessibility and flexible access are key elements.

- There are certain needs for data imposed by the system itself, such as location and cycle time information for use in the dispatch function.

- Mine operators request the means to address information by enquiry for a wide variety of operating results over named time periods.

- Detailed equipment performance and condition information is required by maintenance staff for effective planned maintenance, and by mining engineers for the analysis of trends and effective planning.

5 CONCLUSIONS

The investigating team concluded, based on their interviews with two participating mines, and with 14 other mines selected for their directly related experience, the following:

- EQUIPMENT MONITORING is a high priority, along with a significant interest in DATA TRANSMISSION as it applies to acquiring the data generated in a prompt and efficient manner. Views varied as to what exactly should be monitored among the options available on the market. Some form of payload control is desired, but operators express a lack of confidence in current technology. The requirements set out in the following section reflect a broad target that will satisfy the most important needs expressed.

- The integration of the DATA TRANSMISSION features associated with vehicle monitoring and truck dispatching, or with other functions such as a voice radio network, is not desirable. Improvements can be made in the special purpose technology used by various systems today.

- SIMULATION, as a stand alone function for "What if" analysis received very little attention and is not regarded as important to the mine operators.

- Optimum TRUCK DISPATCHING is a high priority, along with SIMULATION techniques to provide optimization for this purpose, and the necessary DATA TRANSFER technology.

- Users seeking computerized dispatching are split on the question of LOCATION MONITORING, some preferring to involve the truck driver and some preferring to eliminate his involvement. We conclude that the ideal system will have optional discrete location

monitoring to permit a mine operator to fully automate the dispatch function if he so desires. Continuous or universal LOCATION MONITORING received no support. We conclude that a reliable and compatible form of roadside beacon is the maximum requirement.

- DATA BASE technology that will assemble the wealth of data collected and allow query based reporting is seen as a valid objective by all users.

Taking into account these conclusions, the requirements set out in the following section reflect a practical and desirable selection of technologies that can be brought together as an integrated system from which each mine operator might choose the specific features that are seen to be useful in his operation.

6 REQUIREMENTS

The requirements spelled out below are necessarily general at this stage of our investigation. The participating mines (Westar and Suncor) are expected to contribute criticism and expansion of the details of functionality described.

6.1 General

It is a primary requirement that all modules function in harmony with all other modules, and that each functions effectively independent of any other module of the system.

- Computer hardware shall consist of 80286 and 80386 based micro computer(s).

- User interfaces shall be similar for all modules, emphasizing few keystrokes and standard key functions among all modules. Point and shoot devices, such as a mouse, are desirable where applicable.

- Communications strategies shall be similar for each module, and at the minimum, each module will be capable of communication with all other modules that it might be required to address.

6.2 Simulation

There are two primary objectives of the simulation sub-system. They are to provide a very short range operating strategy to guide the dispatching module and shift supervision during the course of this shift, and to provide a tool for longer term analysis such as the evaluation of an equipment purchase (What if?). Of these two purposes, the first is of greater importance.

- Input parameters are:
  Mineral quality by working face
  Required blend (range)
  Loading time by individual shovel and truck fleet combination
  Travel time by truck fleet and route segment
  Trucks available, by fleet
  Shovels available, and working faces available to each

- The simulation system shall obtain current operating times, and other equipment performance characteristics needed, from real time data gathered during a recent shift through the dispatching program.

- For longer range planning and what if analysis, further input requirements include mine wide constraints, such as:
  Total trucks and shovels by fleet
  Availability by fleet

- The simulation program must provide a reliable forecast of results when any of the operating parameters are changed.

- For the guidance of the dispatching module, produce a number of operating strategies that meet shift objectives for quality and production.

- Report an identification number for the best (n) workable plans produced, in order of production resulting from each.

- Display a key indicator for each shovel, such as percentage of waiting time, digging time or truck waiting time, upon which the operator can base his choice of plans. He will accept lesser production for uniformity of this indicator, in preference to extremes which may not be achievable.

- Produce input required by the dispatching module to cause it to operate according to the selected strategy.

6.3 Dispatching

Two separate and distinct dispatching systems are required, each to serve a different purpose. The objective of the first is to minimize equipment waiting time. The objective of the second dispatching subsystem is to optimize production results among all working faces (Maximum production with minimum travel) while maintaining mineral blend into the primary crusher within the desired range. Both will:

- Use information received by radio link from operating equipment to determine loading times by shovel / truck fleet, travel times over each route segment for each truck fleet, truck status and location, etc.

- Provide fall back positions, to ensure continued reasonable operation despite failures in any of the system's components.

- Provide the full range of dispatcher displays currently offered by PMCS, to display and control production and operating factors.

- Dispatch trucks according to the mines needs and policies.

The strategy that is required to include blend control as a constraint in the dispatch decision process will include the following features:

- Accept and use output from the simulation program to define the operating objectives of this shift.

- Dispatch trucks according to the strategy supplied by the simulation program to achieve the objective stated above.

- In the event changes occur to prevent the maintenance of the required blend, such as a key shovel becoming unavailable, warn the dispatcher.

6.4 Equipment information

While there is great interest, there is no clear consensus on this item. Operators express a variety of needs encompassing all of the following functions. Features most requested are:

- Protection of equipment from damage or failure due to abuse or loss of fluids

- Provide detailed operating time information for the use of mining engineers and maintenance planners

- In real time, it will report the operating information required by the dispatching program.

6.5 Data transfer

It is the objective of the communications module to handle all of the data radio needs of the integrated system in an efficient manner, and in a way that coexists peacefully with the voice radio system.

- It is desirable for communications involved in the dispatching function to occur immediately, whenever there are any data to transmit, using an interrupt strategy.

- Data not necessary for real time processing may be downloaded periodically using a polling technique.

- Voice and data are carried on separate frequencies, and probably use separate radio sets to avoid frequency switching and message delays. (For the purpose of this report and the resulting system, voice radio will not be considered a part of the integrated system. Each mine has a voice network, and no incentive to change.)

- It may be practical to use a separate frequency (and radio) for each function, rather than attempt to force the variety of technologies into one mold. We note that the various technologies under examination each have a functional communications strategy that works, and each has a frequency crowding limit of use.

6.6 Location devices

It is the objective of the location detection strategy selected, to provide a current view of monitored equipment in relation to a map of the mine, and to provide such location information to the dispatching program as is required for it to perform its work.

- At the minimum, data will be provided to the dispatching computer at points in the truck cycle when dispatch decisions are to be taken.

- It is desirable for sufficient truck movement information to be gathered and reported, that the trucker need not be required to enter and transmit status or location information to achieve effective dispatching. At the mine operator's discretion, dispatching can be fully automatic or utilize truck driver entered data.

- Represent equipment location on a high resolution screen carrying a graphics map of the mine.

6.7 Data base

It is the objective of the selected data base system to store information gathered from the various subsystems hereof, and to provide ready access to that information in a form useable to mine operators.

- The presence of the data base must not degrade the performance of the PMCS monitor.

- This suggests that the data base will be updated by an independent process, or processes, resident on some machine other than the machine on which the PMCS MONITOR is run. This further implies that there must be a transaction processor, or server, to put things into, and take things out of, the data base.

- The data base must be accessible by several users simultaneously. At a minimum this means that any number of users can read information at 'the same time' as other users are reading or writing. It is acceptable that only one user can write at a time. A transaction processor, or server, would deal with this requirement by queuing requests.

- The data base must provide users with a query/report writing facility that is 'ad hoc' in nature. This means that users of the facility can create their own 'programs' and 'reports'.

- The data base must support the integration of the other project components and provide a vehicle for exchange of information between them. Other project components are taken to mean:

Operation Modelling & Simulation
Vehicle Information
Dispatching
Vehicle Location

- The data base will not necessarily replace the current PMCS data structure which is specially designed for MONITOR's and MIS's needs. In fact, due to the inherent efficiency of the current data structure, it is very probable that the data structure will not be replaced by the data base facility.

July 19th, 1988 Appendix "A"

Mines whose staff were interviewed and whose opinions are therefore reflected in this report and statement of requirements.

Byron Creek Collieries

Crows Nest Resources, Line Creek

Fording Coal Ltd

Gregg River Resources

Highland Valley Copper

lron Ore of Canada

Quebec Cartier Mining

Suncor Inc*

Smoky River Coal Ltd

Wabush Mines

Westar Mining Ltd, Greenhills*

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*Participating mines

APPENDIX II

CONCEPTUAL DESIGN

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M E M O R A N D U M

26 July 1988

To: File

Fm: L.J. Tolton

Sj: CANMET Integrated Truck/Shovel Mine Management System, Overall System Requirements Outline

This memo is an update to my memo of 17 July 1988. It sets out the principal requirements of the CANMET Integrated Truck/Shovel Mine Management System.

The Project will investigate and demonstrate the following portions of an integrated Truck/Shovel Management System:

a. Computer Simulation Program:

The Computer Mine Simulation portion of the project will investigate and demonstrate as follows:

The ADOPT mine simulation methodology will be interfaced to the Wenco Production Monitor & Control System. PMCS will provide on-site generated data to the simulation program. This data is generated in real time by data collection devices attached to various mine site equipment. PMCS also accepts data from the mine dispatcher (or Pit Controller), and from other mine departments. This data, once suitably verified and formatted will be transmitted to the simulation model when required.

The ADOPT mine simulation methodology will make available information to the dispatching portion of the system, and to the mine's supervisory, engineering, and managerial personnel. Mine plan (or shift targets) are transmitted to the dispatching program as required, and optionally, to PMCS.

b. Dispatching Program:

The Dispatching portion of the project will investigate and demonstrate as follows:

A simple deterministic model of dispatching will be investigated and demonstrated, and used as a basis of comparison and evaluation for other methods of dispatching. The WENCO model of deterministic dispatching to minimize truck waiting time will be employed for this portion of the study.

A sophisticated LP model of dispatching will be investigated and demonstrated. Differences in cost and in results will be determined. The AD OPT model of NLP truck dispatching will be employed for this portion of the study. It will receive information from various other system component as follows: 1) Mine plan & shift targets are received from the simulation sub-system. 2) vehicle cycle times and current location information is received from the PMCS Monitor. Equipment availability information and equipment productivity information is received from the Equipment Information system. Dispatch instructions are sent to the PMCS Monitor for transmission to the mining trucks.

c. Equipment Information System:

The Equipment Information portion of the project will investigate and demonstrate the integration of equipment information as follows:

Equipment maintenance information will be used as input to the mine simulation sub-system, as will equipment production information. Additionally, maintenance information may also be sent to the PMCS Monitor. Availability & Utilization information may be sent from the PMCS Monitor to the Equipment Information system.

d. Data Transfer System:

The Data Transfer system to be investigated & demonstrated will be as follows:

A proprietary protocol using an HSC modulation scheme will be implemented to transfer data between the mining vehicles and the PMCS Monitor. The scheme is currently used by Wenco in several operations of a similar nature. The purpose of the demonstration will be to establish the practicability of certain enhancements to the basic method, namely, the addition of a location monitoring scheme (beacons).

Optionally, an experiment may be run using the same protocol and an MSK modulation scheme. The purpose of this would be to determine the increase in network capacity created by the change.

Output from the investigation will include a method of expressing a radio network's capacity in terms that are meaningful to mining operators, it having been adequately demonstrated that Baud rates and protocol types are reasonably meaningless.

e. Mobile Equipment Location Devices:

The project will investigate and demonstrate the use of Mobile Equipment Location Devices as follows:

Vehicle position information will be transmitted to the PMCS Monitor. The Monitor will forward it to the other sub-systems as required. These include: 1) the dispatching sub-system, 2) the location display sub-system.

The location display sub-system provides a real-time, graphical image consisting of a (schematic) mine map, and the current location and state of pertinent mining equipment upon it.

The location monitoring sub-system will test the use of beacons. Nothing in the design of the overall system will exclude the use of more sophisticated location monitoring systems such as vehicle borne navigation computers, satellite based position sensors, etc.

f. Data Base:

The project will investigate and demonstrate the use of a commercially available data base system as follows:

Data from all other sub-systems will be stored in an efficient and useful fashion so as to make it available for 1) communication between sub-systems where appropriate, 2) routine, pre-defined Management Information Reports and Engineering Analyses, 3) special purpose, ad hoc Management Information Reports and Engineering Analyses.

The data base integration will be achieved in such a way as to allow for the substitution of other commercially available packages should it be desirable to do so.

Specification of Hardware:

The CANMET Integrated Truck/Shovel Mine Management System will be configured as follows, in its full implementation. (During unit testing, various modules will be configured to work in stand-alone mode.)

1. THE LOCAL AREA NETWORK SERVER and DATA BASE SERVER. This machine will function as a network server, as a data base server, and as the 'Management Information' machine. Its purpose will be to act as a repository for shared data between the various applications, ie: Equipment & Mine Description Tables, Pit Status Table, etc. Application modules will place data into the server's data base using the transaction processor. All Management Information reports will be produced on this machine. It will be a 386 based unit (such as a COMPAQ 386/25) with substantial disk memory (minimum 40 Mbytes). Because the unit will handle large numbers of Data Base transactions, the disk(s) should be of high speed (at least 25 millisecond seek time - average). It should be equipped with an EGA (or better) and compatible colour monitor. A telephone modem will be attached to the LAN server, to provide a method for the delivery of remote support.

2. THE LOCAL AREA NETWORK. The topology of the Local Area Network will be Ethernet compatible. This will ensure connectivity with the widest possible range of devices. The speed will be at least one million bits per second (1 Mbps). The network functions should be carried out on a network interface card, or in extended memory, so as to leave the main portion of the machines available for routine processing.

3. MONITOR (& MONITOR-B). This machines serves as the central real time display. It displays equipment state, assignment, production, etc. It must be fast (at least a 80286 based machine with a 10MHz clock). It must be equipped with an EGA (or better) an compatible colour monitor. It attaches to the Equipment Production portion of the Data Transmission system. MONITOR-B is optional..MONITOR stores all data files, check points, etc. on the LAN server if it is installed. MONITOR (& MONITOR-B) read startup & checkpoint information from the LAN server. MONITOR & MONITOR-B share an RM110 Radio Modem for communication with mining equipment.

4. SIMULATION & DISPATCHING. This machine carries out the mine simulation computations for various situations as directed by the Pit Controller, Mine Supervisor, etc. All mine descriptive data is received from the LAN server. Boundary conditions (What-If scenarios) may be made up, or retrieved from the LAN. The results of simulations are stored on the LAN server, where they may be accessed by other applications (ie: DISPATCHING, & MONITOR).

   It also carries out the dispatching computations, and passes the results of these to the MONITOR computer. DISPATCH results can be passed to the MONITOR in a number of ways to deal with different situations. For example, the DISPATCH can be a response to a specific request, or it can be a set of future dispatches (to cover the possibility of the DISPATCH computer being unavailable), or it can be a set of dispatch rules (a strategy) by which MONITOR can make its own dispatch decisions for a period of time. These results are all stored on the LAN server so that they can be retrieved by the MONITOR computer (or the MONITOR-B computer) at any time.

5. EQUIPMENT INFORMATION. This machine gathers information about equipment state & location from two sources: 1) from its own radio network, and 2) from the MONITOR's network. This latter is received over the LAN. The EQUIPMENT INFORMATION machine displays, on a continuous basis, the location and status of mining equipment. The location and status information is displayed in real time on a schematic map presentation. If production information (ie: load size) is gathered by this system, it is transmitted to the MONITOR machine over the LAN. Selected equipment information is stored on the LAN server, in the Data BAse for retrieval by Engineering, Maintenance, etc.

Table of recommended hardware & software:

1. Local Area Network Server and Data Base Server	Compaq 386/25 with - 2Mb main & extended memory - 80Mb 25Ms Hard disk - Hayes 1200/2400 Modem - ARCNET (or sim.) network i/f - EGA (or EGA/VGA) graphics i/f - NEC Multisync Monitor - Mouse or Trackball
2. Local Area Network	Cables, connections & interface cards - To be specified
3. MONITOR	Compaq 286 with - 1Mb Main & Extended memory - 40Mb 40ms hard disk - ARCNET (or sim.) network i/f - EGA (or EGA/VGA) graphics i/f - NEC Multisync Monitor - Mouse or Trackball - Serial I/O interface
3(b). MONITOR-B	Compaq 286 with - 1Mb Main & Extended memory - 40Mb 40ms hard disk - ARCNET (or sim.) network i/f - EGA (or EGA/VGA) graphics i/f - NEC Multisync Monitor - Mouse or Trackball - Serial I/O interface
4. SIMULATION & DISPATCHING	Compaq 286 or Compaq 386/25 (as required) with - 1Mb Main & Extended Memory - 40 Mb 40ms hard disk - ARCNET (or sim.) network i/f - EGA (or EGA/VGA) graphics i/f
5. EQUIPMENT INFORMATION	Compaq 286 with - 1Mb Main & Extended Memory - 40Mb 40ms hard disk - ARCNET (or sim.) network i/f - EGA (or EGA/VGA) graphics i/f - Serial I/O interface

Software:

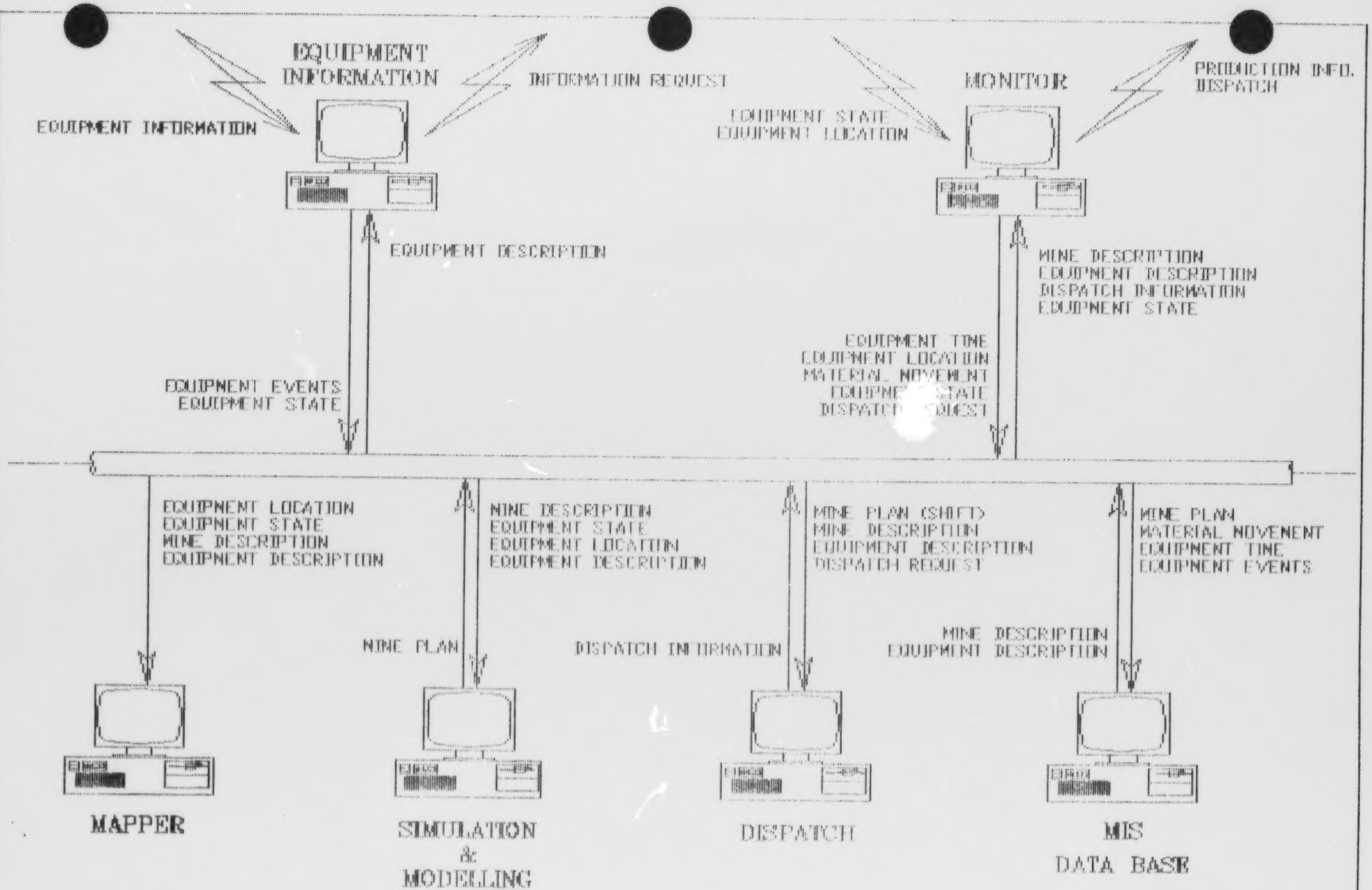
MS-DOS version 3.31 (or higher)
Waterloo Net (or other as determined)
Oracle RDBMS (and required options)
PC-Anywhere or other remote server

plus Application Software

WENCO PMCS (MONITOR & MIS)
AD OPT Simulation
AD OPT Dispatcher
WENCO Location Mapper

The following Figures are attached to this memorandum:

Description	FileName
1. Functional Configuration	cmp_01
2. Data Flow - Context	cmp_02
3. Applications	cmp_03
4. Configuration (Concept)	cmp_04
5. Configuration (Concept)	cmp_05



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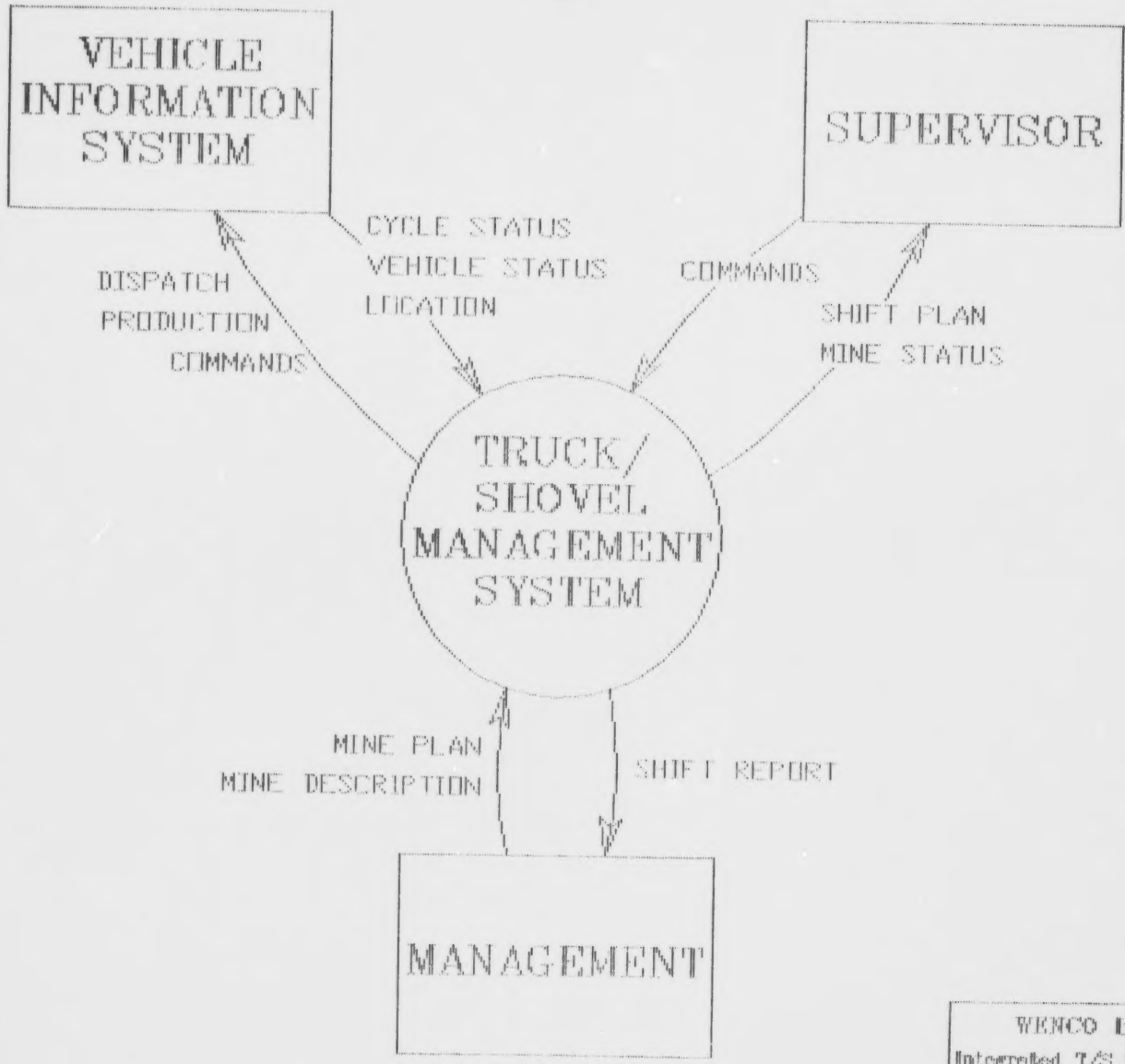

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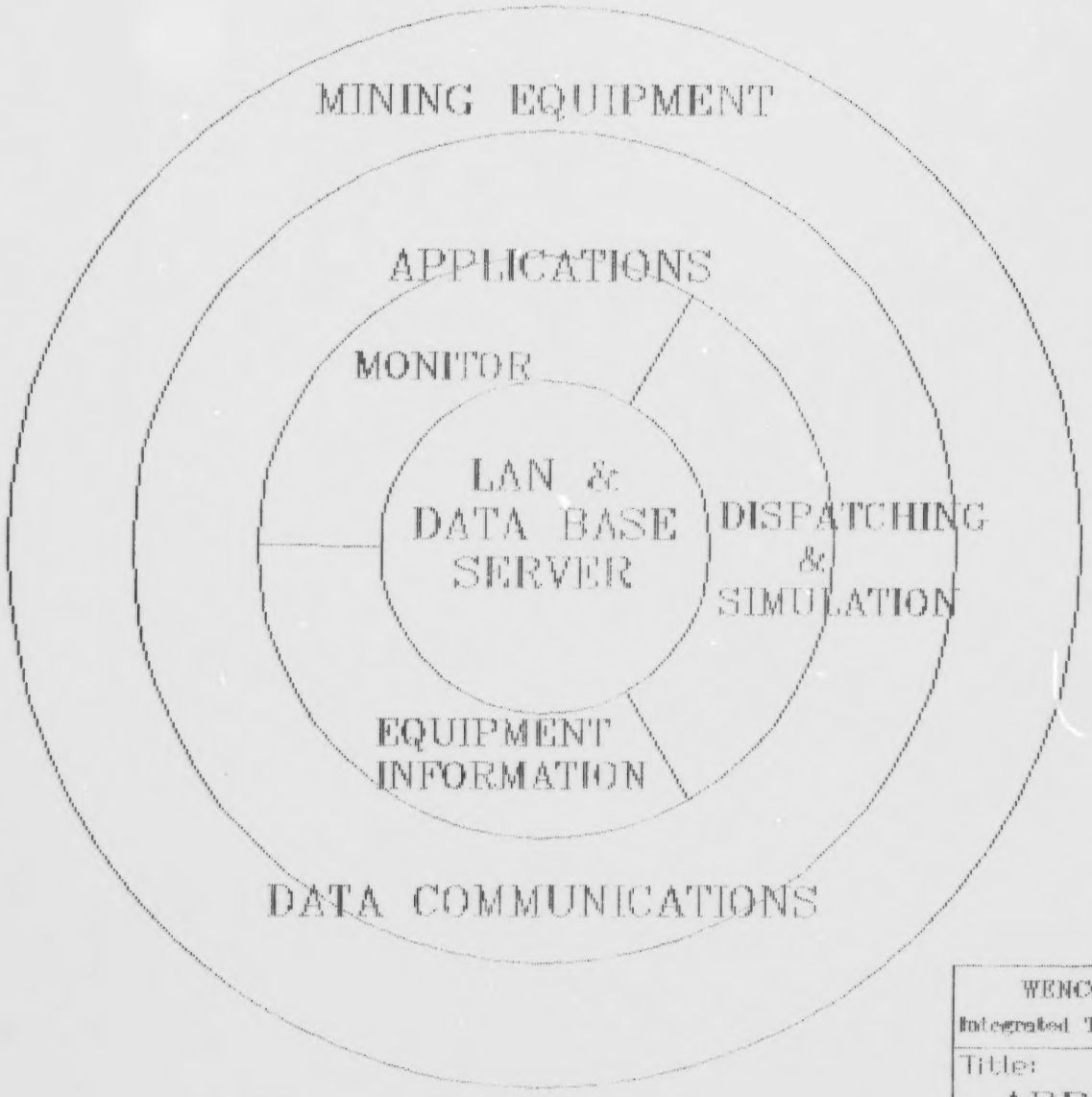

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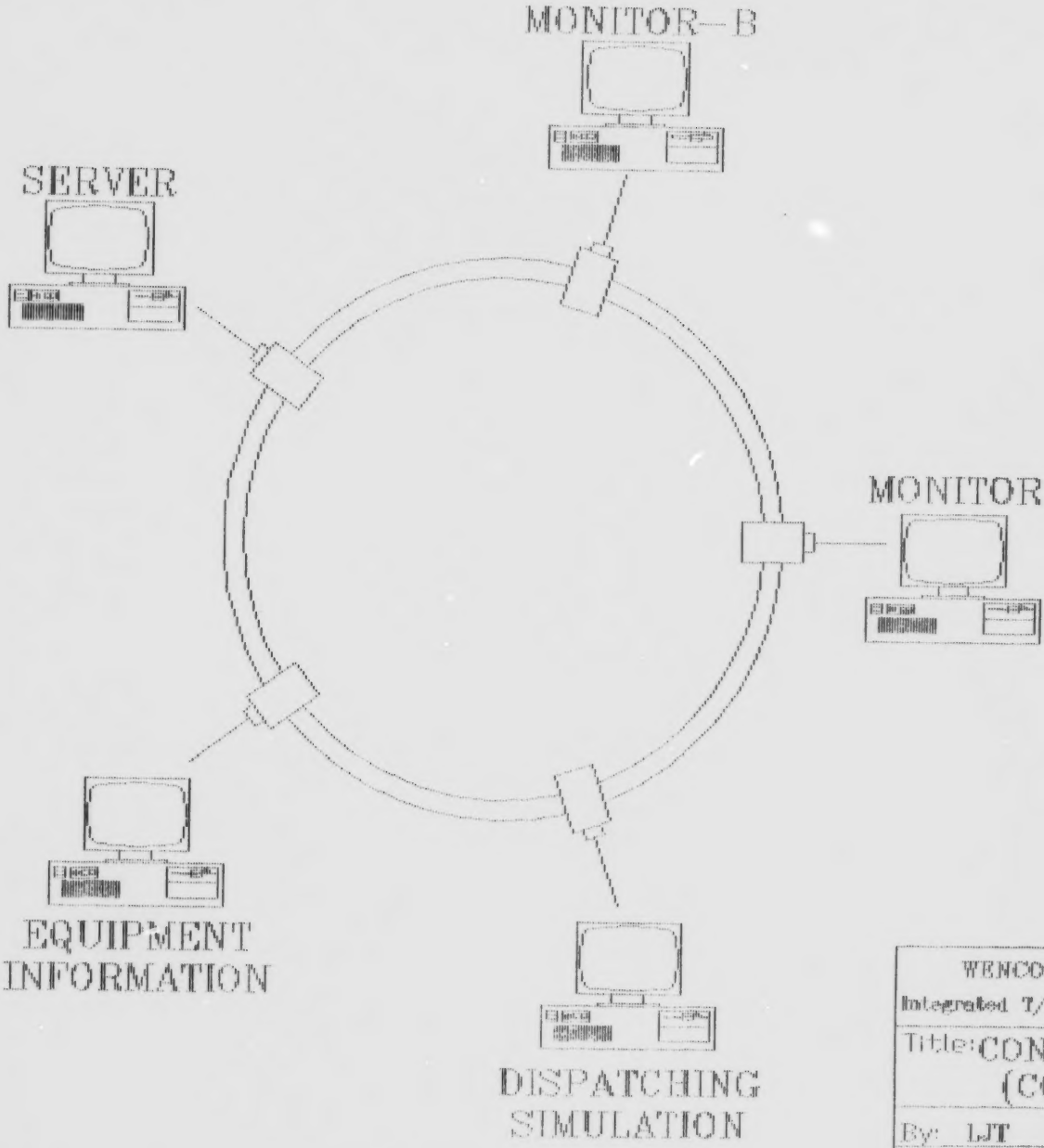
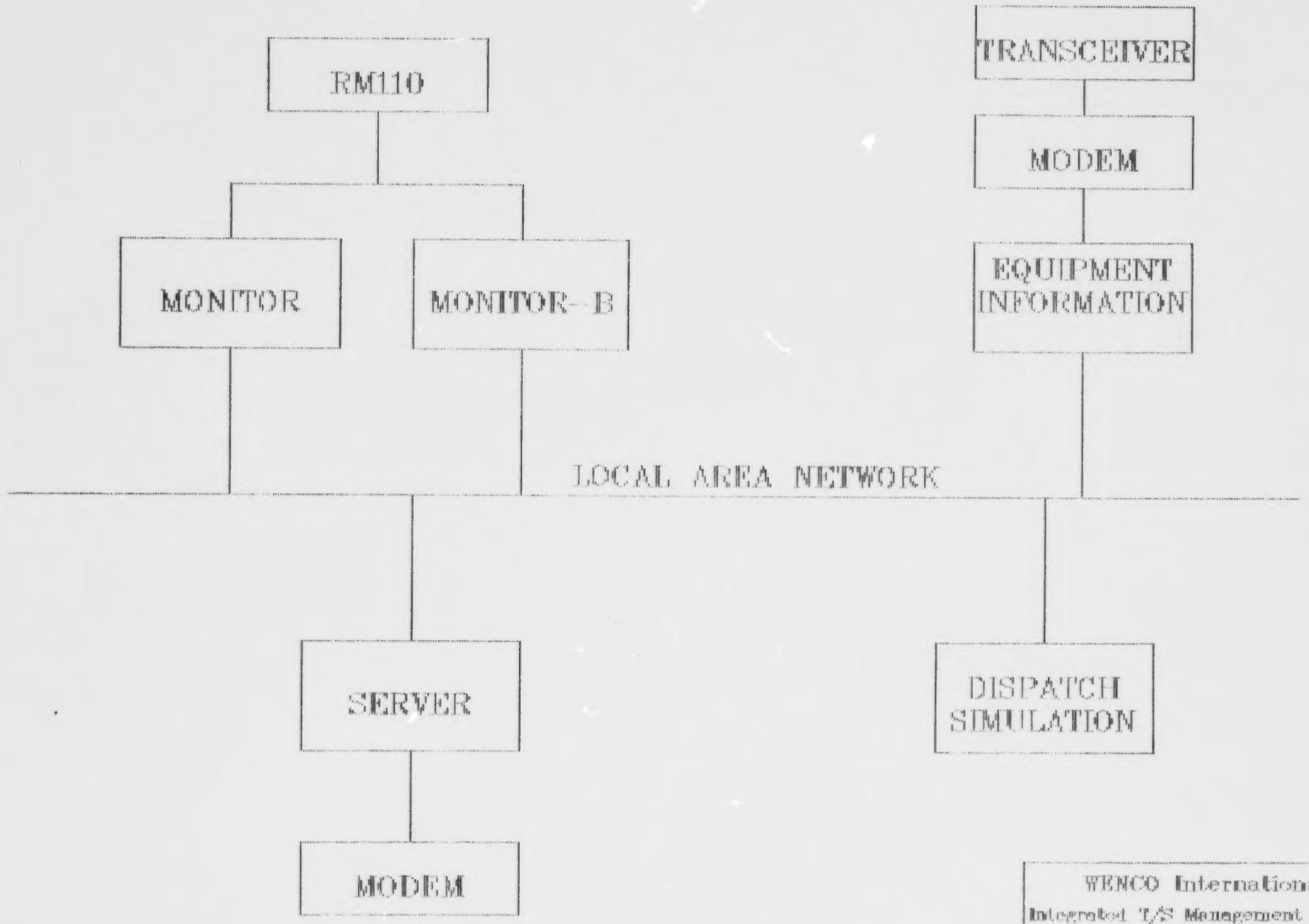


WENCO International
Integrated T/S Management System

Title: CONFIGURATION (CONCEPT)

By: LJT | Dt: 88/07/26

FileName: CMP_04.DWG



WENCO International
Integrated T/S Management System

Title: CONFIGURATION (SCHEMATIC)

By: LJT | Dt: 88/07/26

FileName: CMP_05.DWG

APPENDIX III

SIMULATION, DETAILED ANALYSIS

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August 16, 1988

INTEGRATED TRUCK/SHOVEL MANAGEMENT SYSTEM

TECHNICAL EVALUATION:

SIMULATION

Submitted to:

CANMET

By:

WENCO International Mining Systems Ltd.

ABSTRACT:

This paper is a technical evaluation of simulation strategies for truck/shovel operations in open pit mines.

The strategy recommended for the Integrated Truck/Shovel Management System is to use the planning modules contained in AD OPT's truck dispatch system. Desirable features from other simulation models can be added to this program if required.

INTRODUCTION:

WENCO International Mining Systems Ltd. has been commissioned by CANMET to articulate the user requirements for integrated truck/shovel operating and management systems in producing surface coal or oil sands mines. This project represents an introductory phase to a larger proposed project (WENCO, 1987). The larger project includes the development, demonstration, and evaluation of the system(s).

Note that one of the key points in the proposal is that the Integrated Truck/Shovel Management system is to use WENCO's PMCS product as a base system. The modules developed for this project are to be "plugged" into PMCS.

The project proposal (WENCO, 1987) has divided the system into discrete modules, one of which is the SIMULATION module. This module is responsible for producing two types of simulations:

1. Short term mine plans that supply first-line, in-pit mining supervisors with shift set-up decision support. The short term mine plan will also provide input for the mine's real-time truck dispatch program. Input will come from:

   - real-time data that has been gathered from the previous shift(s),
   - the mine's long range plan, and
   - the mine's current production and quality marketing requirements.

2. Longer term economic simulations that will be used for mine planning and equipment selection etc.

PROPOSED PHASES OF SIMULATION:

Simulation Defined:

First, simulation in the context of the proposed (WENCO, 1987) Integrated Truck/Shovel Management System must be defined.

The simulator's function is to produce operational truck/shovel shift plans together with the plans' expected results. The program simulates the operation of the mine's trucks and shovels and produces plans for their optimum utilization (i.e. given a mine layout and a set of production targets, the simulator will place the shovels in the mine and estimate the required truck volumes in such a way(s) that the production targets will be realized with minimum cost).

Note that the proposed simulator is NOT an event-to-event real-time simulator. This type of simulator is used to simulate messages that are transmitted from mobile equipment to a central computer. It actually a radio network simulator as opposed to a mine simulator.

Simulation Development Phases:

The proposal (WENCO, 1987) outlines a four phase simulation development plan. Phases I, II, and III will provide planning support directly to the first-line in-pit mine supervisors. Phase IV will provide support for longer range planning (mine layout, equipment selection, etc).

Phase I: Optimal shift plan.

An interactive program will calculate a set of optimal shift plans. Shovel locations, materials, and digging rates will be matched with truck frequency and routing. The calculated plans will be such that the shift's production and quality targets will be realized.

Phase II: Optimize maintenance time.

Scheduled and unscheduled maintenance time is to be added to the program developed for Phase I. The shift plan targets are to be met even when some equipment is unavailable.

Phase III: Interface a shift plan to the real-time dispatching algorithm.

The shift plan and the real-time truck dispatching algorithm will be interfaced. The dispatching algorithm must dispatch trucks in such a way so that the shift plan is realized. Therefore, the plan must be made available to the dispatching algorithm.

Phase IV: Longer term economic simulation.

This encompasses the integration of all information from the previous phases. The data is to be statistically reduced to a set of factors that will be used with economic and blending factors to optimize the mine plan on an economic basis over a longer time horizon.

The resulting program(s) are to be interactive so that input parameters can easily be changed i.e. "what if" senarios can be quickly investigated.

RECOMMENDED SIMULATION STRATEGY:

AD OPT's planning algorithm (Soumis et al, 1988) is recommended as the base or core of the simulation module in the Integrated Truck/Shovel Management System.

This strategy is recommended because:

- This model already meets the requirements of Phase I.
- This model already meets the requirements of Phase II.
- The model uses a combination of Linear and Non-Linear programming. The non-linear techniques yield optimum solutions that are more stable in the real-time dispatching domain than linear techniques. This is due to that fact that the non-linear solutions trend towards the optimal solutions for all parameters. Linear solutions product solutions whose parameters may sit at the extreme limit of acceptability (Soumis et al, 1988).
- AD OPT's dispatch logic has been selected for the Integrated Truck/Shovel Management System's dispatch module. By using AD OPT's simulation, a high degree of compatibility and integration will be achieved.

This recommendation does not belittle the other simulation models that have been evaluated. Where possible, their suggestions, experience, and methods will be incorporated into the final product where ever it is deemed useful.

SIMULATION COMPARISON:

There are only two simulation models that have been seriously considered for inclusion in the Integrated Truck/Shovel Management System. The are:

- AD OPT's system that is installed at Quebec Cartier's iron ore mine, and
- Modular Mining Inc!s simulation module that is part of its DISPATCH product.

These algorithms are considered here because they are the only simulators (to the authors' knowledge) that produce operating shift plans that are coupled to real-time truck dispatching systems.

Other simulators were looked at and rejected because their goals were incompatible with those of the Integrated Truck/Shovel Management System.

The algorithms were evaluated using the following criteria:

Mathematical Soundness:

Both received high marks for mathematical soundness. However, AD OPT's strategy was graded higher due to its use of non-linear programming in formulating a shift's operational plan. The non-linear programming technique tends to make the operational plan centre on the optimal set-points while MODULAR's LP model can operate at its extreme limits (Soumis, 1988).

Simulation Time Frame:

Both produce practical shift plans. Modular's system offers a medium term mine simulation option; AD OPT does not.

Field Testing:

MODULAR has installed its system in several (about fifteen) mines around the world. AD OPT's algorithm is currently operational in one Canadian mine.

SIMULATION DESCRIPTIONS:

The following are summaries of several truck/shovel simulation systems.

AD OPT:

Purpose:

This simulation program was written specifically to supply a dispatch algorithm with a optimum short term shift plan. It also supplies the in-pit supervisors with shift set-up decision support.

Input:

The simulation's inputs are:

- Production and product quality objectives,
- the number and type of available trucks and shovels,
- the mine layout, the locations of material sources and dumps together with the material quality.

Output:

The simulation's output is a set of mine plans that :

- position the shovels in the pit,
- selects the truck volume required to service the shovels,
- selects the truck routes,
- supplies an optimum plan to a dispatching algorithm.

Several optimum plans are presented to the user. The user can select one that meets the mine's more global requirements. The user can also change many of the input parameters interactively so that the simulation can quickly respond to in-pit changes.

Compatibility with Dispatching:

AD OPT has specifically tailored the simulation to work with a dispatch algorithm.

Programming Method:

The simulation has been programmed in FORTRAN. It consists of a two step process:

Step 1: Equipment Choice: This step is a "rough cut" Linear Programming program that suggests optimum shovel locations and materials.

Step 2: Operational Planning: This step fine tunes the plan suggested by Step 1. It uses a non-linear programming method to select truck volumes and routes that match the shovel set-up.

Field Installations:

This simulation program is currently being utilized at Quebec Cartier Mining.

MODULAR MINING INC.:

Purpose:

This simulation program was written specifically to supply a dispatch algorithm with a optimum short term shift plan. It also supplies the in-pit supervisors with shift set-up decision support.

Medium range planning is supported for "what-if" types of analysis.

Input:

The inputs consist of:

- pseudo cost functions,
- production targets,
- material quality factors,
- plant feed rates,
- mine layout (routes),
- route travel times,
- etc.

Output:

The simulation produces the required material flow rates on the mine's routes. The flow rates are achievable and optimum. The flow rates are input to MODULAR's dispatching algorithm.

Compatibility with Dispatching:

MODULAR has specifically tailored the simulation to work with a dispatch algorithm.

Programming Method:

The simulation has been programmed in C. It consists of a two step process (both steps use Linear Programming techniques):

Step 1: Overall Optimization - This step minimizes a pseudo cost functional to minimize rehandle, force a solution near the critical blending constraints, and meet the desired feed to the plant.

Step 2: Production Maximization - This step maximizes production by minimizing the haulage capacity needed for mine shovel coverage.

Field Installations:

This simulation (and the companion dispatching algorithm) has been installed at several mines (about fifteen) throughout the world.

OTHER SIMULATION PROGRAMS:

A number of simulation programs were investigated (Runge, 1983; Yu & Hucka, 1985; Chatterjee & Brake, 1981; Nenonen et al, 1981). All of them were not suitable for use in the Integrated Truck/Shovel Management System because they were designed to be used as mine planning tools and not as mine operational tools.

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APPENDIX IV

DISPATCHING, DETAILED ANALYSIS

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August 16, 1988

INTEGRATED TRUCK/SHOVEL MANAGEMENT SYSTEM

TECHNICAL EVALUATION:

VEHICLE DISPATCHING

Submitted to:

CANMET

By:

WENCO International Mining Systems Ltd.

ABSTRACT:

This paper is a technical evaluation of truck dispatching strategies for open pit mines.

Two algorithms are recommended for use in the Integrated Truck/Shovel Management System:

a. a simple deterministic algorithm that minimizes waiting time (developed by WENCO International), and

b. a sophisticated algorithm that bases dispatch decisions on an optimized short-term mine plan (developed by AD OPT).

INTRODUCTION:

WENCO International Mining Systems Ltd. has been commissioned by CANMET to articulate the user requirements for Integrated Truck/Shovel Operating and Management Systems in producing surface coal or oil sands mines. This project represents an introductory phase to a larger proposed project (WENCO, 1987). The larger project includes the development, demonstration, and evaluation of the system(s).

Note that one of the key points in the proposal is that the integrated truck/shovel operating and management system is to use WENCO's PMCS product as a base system. The modules developed for this project are to be "plugged" into PMCS.

The project proposal has divided the system into discrete modules, one of which is the DISPATCH module. This module is responsible for assigning destinations to mining haulage vehicles on a real-time, per trip basis.

There are several commercial open pit mine truck/shovel dispatch systems on the market. These are currently operating in several mines. Also, there are several truck/shovel dispatch strategies which have be proposed in the technical literature.

This paper evaluates existing truck/shovel dispatch strategies and recommends two for use in later phases of the project.

PROPOSED LEVELS OF DISPATCHING:

The proposal (WENCO, 1987) outlines three levels of dispatching for investigation:

a. simple deterministic,

b. simplistic LP, and

c. sophisticated LP.

Existing algorithms that could (and are) be used in mines have been found for two of the three levels: simple deterministic and sophisticated LP.

Simplistic LP algorithms were reviewed and found to be impractical for real-time truck dispatching. Their primary utility is for simulation and computer assisted dispatching.

RECOMMENDED DISPATCHING STRATEGIES:

The following is a summary of recommended algorithms.

Simple Deterministic:

The algorithm currently used by WENCO's PMCS (Sadler, 1988) is recommended because:

- It is currently being used successfully in two mines.
- It is currently installed in PMCS and is available for improvement and enhancement.

The primary features of this strategy are (Sadler, 1986):

- It minimizes equipment (trucks and shovels) waiting time by dispatching trucks to the first available shovel.
- It groups shovels; shovels in a group share a pool of trucks.

Shovel locations (materials) and the number of trucks assigned to a shovel group are determined manually based on real-time statistics that are tracked by PMCS.

Methods of improving this type of algorithm are discussed in the literature (Hagenbuch, 1987).

Sophisticated LP:

The algorithm proposed by AD OPT (Soumis et al., 1988) is recommended because:

- It is has been successfully demonstrated in a mine.
- It remains stable when the mining situation changes.
- Its calculated optimal parameters trend towards optimal values smoothly due to the use of a non-linear optimization procedure.
- Its shift planning program can be used as the simulation sub-system for the Integrated Truck/Shovel Management System.

Note that this algorithm is not strictly a Linear Programming method. It uses non-linear programming methods.

The primary features of this strategy are:

- The program is divided into three parts:

1. Equipment Choice:

   A linear programming algorithm determines the shovel placement for the shift. The placement is such that the required volume of material can be produced. The material will also meet the mine's quality objectives. The program is interactive; the operator can adjust the algorithm for external criteria and constraints and select one of several plans that have been calculated.

2. Calculation of Plan:

   A non-linear optimization algorithm determines the individual shovel production rates and the truck servicing required to haul the shovel output. The program is interactive; the operator can adjust the algorithm for external criteria and constraints.

3. Dispatching:

   Each time a truck requests a dispatch, a classical assignment problem is solved that involves the truck in question, all the trucks that will request a dispatch in the near future, and all the available shovels. The truck is dispatched in such a way as to minimize the difference between the planned and expected overall equipment waiting times. The expected waiting times are calculated using real-time moving averages of the in-pit operating times.

ALGORITHM COMPARISONS:

SUMMARY:

The project proposal calls for three levels of dispatching to be developed, demonstrated, and evaluated.

Two strategies have been recommended to be included into the proposed system. The recommendation is based on several criteria:

- mathematical soundness.
- mining soundness.
- proven in-mine track record.
- compatibility with PMCS.

Table 1 summarizes the evaluations.

TABLE 1: Algorithm Comparison***

Algorithm	Mathematical Soundness	Mining Soundness	Track Record	PMCS Compatibility
Simple Deterministic:				
* PMCS	Good	Fair	Yes	Excellent
OBDAS	Good	Fair	No	Good
Simplistic LP:				
HAUCK	Good	Fair	Yes**	Poor
BONATES & LIZOTTE	Good	Poor	No	Poor
Sophisticated LP:				
* AD OPT	Very Good	Good	Yes**	Fair
MODULAR	Good	Good	Yes	Fair

* - Recommended for use in the proposed Integrated Truck/Shovel Management System.

** - Hauck's strategy was installed in 1975 at Quebec Cartier Mining Company, Port Cartier, Quebec. In 1987, it was replaced by the strategy developed by AD OPT.

***- Note that this comparison rates the algorithms on their usefulness to the Integrated Truck/Shovel Management System. Each algorithm performs very well for the applications for which they were originally designed.

RECOMMENDATIONS:

The following is a justification for the recommendations. The discussion refers to Table 1.

Simple Deterministic:

Two simple deterministic algorithms were considered, PMCS and OBDAS. Both are sound mathematically as they deal with a simple time line concept when estimating the next available shovel. The methodologies are very similar.

They are both considered "fair" for their mining soundness. They minimize waiting time which accounts for the greater part of potential gains that accrue from dispatching.

PMCS is currently being used in three Canadian mines and has been demonstrated at a mine in India. OBDAS, to the authors' knowledge, has not been used for truck dispatching in an operating mine.

PMCS is, of course, fully compatible with itself, therefore its PMCS compatibility is excellent. The OBDAS algorithm is similar to the PMCS algorithm and could be incorporated into PMCS without a great deal of difficulty.

Recommendation:

PMCS is recommended as the simple deterministic algorithm for the Integrated Truck/Shovel Management System.

The primary reasons are:

- The PMCS algorithm can be demonstrated, as is, immediately. It is already installed in the PMCS product.

- Improvements and enhancements can easily be added as necessary, i.e. the "good" features of OBDAS could be incorporated. In other words, PMCS offers a sound base for future improvements for this type of dispatching algorithm.

Simplistic LP:

Two Simplistic Linear Programming algorithms were considered, one put forward by Hauck, the other by Bonates and Lizotte.

Both are mathematically sound. They both combine a linear programming planning program with a dynamic programming simulation/dispatch algorithm. They are classified as "computer assisted dispatching" systems as they suggest a dispatch strategy to a human dispatcher who transmits dispatch assignments to the field via the voice radio.

When mining soundness is considered, Hauck's strategy is considered "fair" and Bonates and Lizotte's is considered "poor". Both strategies are limited to small mines due to the manual nature of their user interface. Bonates and Lizotte suffer from a poor choice of linear programming constraint functions. Particularly, the grade constraint that penalizes low grade material without penalizing high grade material; this ignores losses due to ore minerals going to the tailing stream as a result of overloading concentrator circuits.

Hauck's strategy has been used at Quebec Cartier. However, it has been recently replaced by the strategy presented by AD OPT (see below). Bonates and Lizotte's strategy has been untried in an operating mine.

Both strategies would be difficult to integrate into PMCS. PMCS dispatch utilizes good radio communication technology that can send dispatch information directly to the mining equipment. These two strategies would have to be converted from batch simulation programs to real-time dynamic dispatch programs.

Recommendation:

Neither algorithm is recommended for use in the Integrated Truck/Shovel Management System. Both are based on computer assisted dispatching methodologies and are, therefore, restricted to very small mines.

The requirement to develop, demonstrate, and evaluate a simplistic LP dispatching algorithm can be fulfilled by using one of the sophisticated LP strategies discussed below and fixing or eliminating some of the constraints.

Sophisticated LP:

Two sophisticated Linear Programming algorithms were considered, AD OPT and MODULAR MINING SYSTEMS INC.

Both received high marks for mathematical soundness. However, AD OPT's strategy was graded higher due to its use of non-linear programming in formulating a shift's operational plan. The non-linear programming technique tends to make the operational plan centre on the optimal set-points while MODULAR's LP model can operate at its extreme limits.

In terms of mining soundness, both are good. They are fully automatic truck dispatch systems that consider many real-time mining factors.

MODULAR has installed its system in several (about fifteen) mines around the world. AD OPT's algorithm is currently operational in one Canadian mine.

Compatibility with PMCS is only fair for both algorithms. They are large programs that would probably run on a computer that is separate from PMCS. Interfacing would be done through a LAN or RS-232 lines.

Recommendation:

The AD OPT strategy is recommended for use in the Integrated Truck/Shovel Management System. The primary factor is AD OPT's use of non-linear programming, it leads to a more stable operational plan when compared to MODULAR's strictly linear approach.

It is also felt that any desirable features from MODULAR's strategy could be incorporated into the AD OPT strategy more easily that the reverse.

ALGORITHM DESCRIPTIONS:

The following sections describe each of the considered algorithms in more detail.

WENCO - PMCS:

General:

PMCS currently implements a simple deterministic dispatching algorithm. It minimizes equipment waiting time by assigning trucks to the first available shovel.

The dispatch assignment is transmitted to a truck at the dump point or at an intermediate beacon.

Trucks are assigned to shovel groups. A group of shovels share a common truck pool.

Planning functions (i.e. shift start set-up) and blend tracking are done manually. However, PMCS monitors and displays the real-time pit statistics. This gives the operator a convenient tool for adjusting the pit operation so that planning objectives are achieved.

Overall Objective:

The overall objective is to minimize equipment waiting time.

Objective Function:

The algorithm estimates the time when each shovel within the truck's group is clear. The shovel that is clear first gets the truck.

Constraint Functions:

Empty and loading times that are above maximum values are not used in the calculation of the moving averages. This filters out unusually large times that are recorded due to operator error.

Field Evaluation:

This dispatch algorithm is currently operating in two Canadian mines.

HAGENBUCH (OBDAS):

General:

This method (Hagenbuch, 1987) is primarily concerned with minimizing equipment non-productive time. The method's core is described by the following quote:

> "the principal dispatching question to be answered is 'What piece of loading equipment or which dump site will need a truck the soonest and where can a truck get turned around' loaded or dumped 'the quickest?'"

Three levels of dispatching algorithm complexity are presented:

1. Basic,
2. Enhanced Basic, and
3. Enhanced.

The levels use progressively more time segments from the trucks' cycle.

Overall Objective:

The method minimizes equipment non-productive time.

Constraint Functions:

Constraints can be added to the fundamental dispatch formulae in the form of biasing factors. The details of biasing factors are not included in the paper. The biasing factors mentioned are:

- Blend ratio,
- Truck travel time minimization,
- Truck tires,
- Truck queuing time,
- Shovel queuing time,
- Dump capacity,
- Truck queuing at a dump,
- Operator error (misrouting),
- Cross pit travel,
- etc. ...

Field Evaluation:

To the authors' knowledge, this methodology has not been installed in an operating mine.

HAUCK:

General:

The method (Hauck, 1979; Hauck, 1972) consists of an LP algorithm (based on bivalent system equations) and a dynamic dispatching/simulation algorithm.

The method was developed in 1972 when computer hardware, computer software, and radio hardware were more primitive than today. It is a semi-automatic algorithm that required manual time input by the dispatcher. It should be noted that this method could, in principle, be upgraded to take advantage of modern technology.

Overall Objective:

Total production (ore & waste) is maximized.

Objective Function:

A truck is assigned to the first available shovel. The objective function minimizes equipment "non-productive" time.

Constraint Functions:

The constraints (e.g. stripping ratio, blending, required production, stockpile considerations etc.) are accounted for in the dynamic programming phase.

Field Evaluation:

It is believed that method has been installed at Quebec Cartier Mines Ltd.

BONATES & LIZOTTE:

General:

The method (Bonates and Lizotte, 1988) consists of an LP algorithm and a dispatching/simulation algorithm.

It is a semi-automatic dispatching algorithm. It suggests a dispatch strategy to a human dispatcher. The dispatcher transmits dispatch assignments to the trucks via voice radio.

Overall Objective:

The method maximizes production subject to several constraints.

An external, economic constraint is to provide this service to an operation mine at very low cost. Thus the semi-automatic strategy.

Objective Function:

Production is maximized.

Constraint Functions:

Ore production must be less than the crusher capacity.

The overall ore grade for the shift must be greater than or equal to the target grade.

A shovel's production must fall between its maximum capacity and a minimum capacity.

The truck fleet must be capable of physically moving the required shift production.

All shovels must be used.

Simulation:

A simulation program is run based on the output of the LP algorithm. The simulation suggests a dispatch strategy to the dispatcher who then transmits the dispatch decisions to the trucks via the voice radio.

Field Evaluation:

At the time of paper publication, the computer programs were not completed, therefore the method is untested.

SOUMIS, ETHIER, & McInnis (AD OPT):

General:

This algorithm uses a combination of linear programming, non-linear optimization, and dynamic programming.

The dispatch assignment is transmitted to a truck whenever it passes a beacon as it travels empty.

The method consists of three steps:

1. Equipment choice (linear programming).
2. Operational Plan (non-linear optimization).
3. Dispatching (dynamic programming).

Overall Objective:

Production is maximized. Product quality is maintained at (or close to) its targeted goals.

Equipment Choice (LP):

This is an interactive program that presents the user with a set of optimum shift set-ups i.e. shovel locations (materials).

Objective Function:

Production is maximized.

Constraint Functions:

- The blend/quality targets must be with in limits for the shift.
- Each shovel operates at in one location, producing one material.

The operator is presented with a number of shift set-up options. This gives the operator flexibility in meeting both short and long term requirements.

Operational Plan (non-linear optimization):

This step determines the optimal number of truck trips per route for the plan chosen from the Equipment Choice module. i.e. The number of trucks, shovels, and producing locations are fixed.

This is done by solving a network problem with nonlinear costs. The cost functions are associated with:

1. over/under trucking the shovels,
2. using more or less trucks than are available.
3. missing ore quality targets.

These are expressed as non-linear functions.

This module also calculates the planned waiting times. The waiting times are used in the dispatch calculations.

Dispatching:

A truck dispatch calculation is done whenever it passes a beacon on its way back to the shovels.

A non-linear cost function penalizes waiting times that vary from the planned waiting times. This strategy ensures that the mine plan objectives are met.

Field Evaluation:

This algorithm is currently being used in one Canadian mine.

WHITE & OLSON (MODULAR MINING SYSTEMS INC.):

General:

The method (White and Olson, 1976) consists of two LP sub-algorithms (loosely coupled) and a dynamic dispatching algorithm.

1. LP 1: Solves the overall optimization problem.
2. LP 2: Maximizes production.
3. DP : Dispatches trucks.

Overall Objective:

The overall objective of the method is to:

- Maximize production.
- Minimize rehandle.
- Feed the plant with the target amount of material subject to blend requirements.

LP 1 (overall optimization):

Objective Function:

Minimize a pseudo cost function by minimizing rehandle, forcing a solution near the critical blending constraints, and meeting the desired feed to the plant. The solution consists of a haulage vector (cubic metres per hour) for each shovel.

Constraint Functions:

Shovel production must be between zero and the shovel's maximum production rate.

Material flow to the plant cannot exceed the plant's capacity.

Material quality parameters must be maintained in the plant feed. This is done on a real time basis, i.e. the plant feed is within the blend constraints throughout the shift.

LP 2 (Production maximization):

Objective Function:

Maximize production by minimizing the haulage volume that is required to cover all the shovels. The solution consists of a haulage vector (cubic metres per hour) for each route in the mine.

LP Constraint Functions:

The input and output haulage capacity must be equal at each shovel and dump.

The required rehandle capacity must not exceed the capacity of the stockpile equipment.

The haulage vector for the shovels (determined in LP 1) must match the haulage vectors for the routes. This constraint couples LP 1 and LP 2. If the vectors don't match, material is hauled to a stockpile.

Haulage volumes must be positive.

Dispatch (Dynamic Programming):

The algorithm maintains a list of dumping and hauling trucks together with a list of paths.

When a truck requires a dispatch, the algorithm compares all upcoming dispatches with the list of paths and allocates the trucks to paths. The allocation is the best possible match to the plan calculated by LP 1 and LP 2.

Note that the pit is divided into "regions". Cross region dispatching is controlled by the "region cross damping factor".

Field Evaluation:

This strategy has been installed in several mines around the world (White and Zoschke, 1987).

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APPENDIX V

EQUIPMENT INFORMATION, DETAILED ANALYSIS

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1. INTRODUCTION

This report examines various devices which fall under the broad definition of equipment monitoring systems. Two areas of equipment monitoring are covered:

1) vehicle health monitoring, and
2) production monitoring.

The objectives of the different areas of equipment monitoring are covered, giving typical parameters that are of interest to a mine operator.

A review of the available technology is given, in which ten products described. These product cover a wide range of functions and are not always directly comparable even within the same functional areas.

The results of the investigation are discussed. The applicability of the various equipment monitoring devices to the different groups in the mine are presented. These include the following groups: production, maintenance, mine planning and the equipment operators.

Finally, recommendations are made to evaluate products from each of the vehicle health monitoring and production monitoring areas, for later integration into an existing microcomputer based production monitoring and control system. Reasons for the selection of these systems is provided.

2. SYSTEM OBJECTIVES

2.1 Overview

Microcomputer-based equipment information systems have developed either as an adjunct to a company's primary activity of vehicle manufacturing, or independently by smaller companies who have recognized the need for such devices.

Equipment information systems, as referred to in this analysis, cover two areas that are related only indirectly: vehicle health monitoring, and production monitoring.

The results of both types of monitoring can be useful in the mine planning process. Knowledge of equipment productivity can aid in the selection of equipment in the production planning process. The mechanical status of the equipment is also useful to know since the equipment could be more efficiently scheduled for planned maintenance.

Equipment on the mine can be separated into production and support equipment. The production equipment includes haulage trucks, shovels and loaders, and drills. Support equipment includes graders, dozers and other equipment not directly associated with production.

2.2 Vehicle Health Monitoring

Vehicle health monitoring records information related to the mechanical condition of the vehicle. Some of the functions monitored include:

- temperatures
- pressures
- RPM
- speed
- fuel/water/hydraulic levels
- gear shift position
- brake activations
- clutch activations
- lamp status

Some of the parameters monitored are already displayed to the driver through conventional gauges and indicators in the cab.

Health monitoring can be classified into two areas based on the use of the data provided:

1) vital signs monitoring

2) comprehensive monitoring.

Vital signs monitoring systems monitor parameters whose values are critical to the mechanical 'health' of the equipment. Such systems will provide a warning to the operator or other observer that an action must be taken immediately or else serious and costly damage to the equipment will result. An example is engine oil pressure or temperature.

Comprehensive monitoring systems gather operating information for further analysis, generally by someone associated with the maintenance department of the mine. This can include information to be used for predicting the time of component failure based on observed trends in operating statistics, such as pump pressures. Component monitoring can be used for tracking performance and costs of various parts of the vehicle, such as tires, wheel motors, and any other component whose cost or function merits recording.

2.3 Production Monitoring

Production monitoring generally refers to the recording data related to what the machine was made to do, such as recording truck weights, shovels production based on bucket weights, and drill productivity measured by metres drilled. This information is used directly by the production and mine planning groups to quantify results and to for production planning. Some of the items measured include:

Trucks:

- haulage cycle times:
  - loading
  - travel full
  - waiting at destination
  - travel empty
  - waiting at shovel/loader
- delays
  - coffee breaks
  - lunch breaks
  - shift change
  - etc.
- down times (non-production, e.g. mechanical, electrical or structural repairs)
- gradient of roadway
- transmission shifter position
- payload weight
- payload weight distribution in box

Shovels:

- operating time/delays
- loading time
- cycle time
- production
- bucket load
- total cycle time
- swing to truck
- spot time

Drills:

- rotary torque
- rotary speed
- pulldown pressure
- drilling time
- drilling depth

The data can be collected on a real-time basis, or stored on board for retrieval at the end of the shift. If the information is to be used to make production decisions during the shift or is to be used as input to the dispatching system, the information has to be made available real-time. If it is required for shift reports and historical analysis, non-real-time reporting is adequate.

3. AVAILABLE TECHNOLOGY

3.1 ACET Ltd.

The following is a description of a shovel monitoring device supplied by ACET Ltd. of Australia. The information is derived from a brief article in a mining trade magazine. Further information was requested from the company, but to date none has been received.

Shovel Performance and Report Compiler (SPARC) is a computer-based data gathering system for open pit mines using electric rope shovels. Data logged on the shovels is transmitted to a central computer where it is displayed and stored.

For each shovel the mass of each shovel load placed into a truck, as well as the cumulative load, is recorded. This is displayed to the shovel operator and simultaneously transmitted, with other production performance data, to the base computer by a radio link. SPARC provides the shovel operator with a means of loading trucks to within predefined limits without interfering with the normal production cycle, and for management to monitor the shovel performance.

A primary function of the SPARC system is the display of shovel loads to the operator. This is achieved with a small VDU which shows the weight of the current shovel load and the cumulative weight of the load in the truck currently being loaded. The software is a subset of a general process reporting and archiving package and is user configurable with extensive data handling capabilities.

3.2 Advanced Electronic Systems Ltd.

Introduction

The system will gather data from sensors installed in the mobile machine, perform real time monitoring and alarming, and transmit the sensor data to a base computer system located in a maintenance facility nearby.

The major components are the on-board system, base computer and software, and data communications link. The on-board system comprises an operator display unit, sensor interface unit, and the sensors and transducers.

The operator display unit functions as the main interface with the system for operators and mechanics. It permits the setting of alarm setpoints and acts as the alarming device.

The data collected on the machine is stored on board and can be retrieved either by hardwire downloading or by data radio link. The data radio link offered can be an un-modified voice-grade transceiver operating at 2400 bps or a high speed data radio operating at 8000 bps.

The equipment and services included are as follows:

a) Provision of base computer & software

b) Provision of on-board computer comprised of:
   * Operators Display Unit
   * Sensor Interface Unit
   * Sensors and Transducers

c) Provision of two UHF radios for data transmissions

d) Field engineering services for installation & commissioning.

On-board System

The on-board computer system provides automatic monitoring, alarming, and data acquisition functions for heavy mobile equipment. The system has two major components which are:

Operators Display & Keypad

This unit is the operators' and mechanics' main interface with the system. The operator display is a scrolling 24 character alpha-numerical readout that automatically displays the description, current value, alarm limit(s) and a warning message upon detection of an alarm condition.

The display and keypad can also be used as follows:

* To view the output of any sensor in the system

* To view any alarm setpoint

* To enter or edit any alarm limits (upon entry of an authorized password).

* To disable sensors for maintenance purposes

In addition the operators display includes a built in real time clock that time-stamps the data collected. The display also has several built in data communications devices as follows:

* Modem for interface with radio transceivers

* Modem for telephone line connection

* RS 485 interface for connection to the systems internal local area network (SAE Compatible)

* Spare RS 232 port for peripheral equipment.

The operator display is ruggedized, water resistant, and designed for outdoor all weather operation.

Sensor Interface Unit

The sensor interface unit is a NEMA 4 enclosure into which all the sensors and transducers are wired. The sensor interface unit or SIU connects to the operators display by means of a 4 wire data highway. The SIU can be mounted remotely up to 1000 feet from the operators display.

The SIU contains its own microprocessor and performs the following functions:

a) Input protection and filtering

b) Conversion of analog signals to digital

c) Automatic gain and offset conversion for all sensor types

d) Conversion of sensor inputs to engineering units

e) Storage and communications with the operators display unit over the RS 485 LAN

f) Spare RS 232 port for auxiliary equipment

g) Spare and unused closed loop control outputs are also provided in the SIU. This document does not include any automatic control functions but it is worth noting that the capability can be added to the deliverable hardware.

The SIU is totally programmable allowing for any type of sensor or transducer to be connected to the system. This unit can directly connect to low level signals such as thermocouples or strain guards, or can accept high level pre-conditioned signals as well.

In those applications requiring more sensors than one SIU can handle, extra SIU units can be connected to the data highway or LAN to expand the system.

The application to the mining equipment requires only one SIU and this is included in the document.

Data Radio

A mobile radio to be used exclusively for data transmission from the mobile equipment to the base is being provided.

A frequency of 420 MHz is recommended as this is currently a favored band by the DOC for data transmission and as it is a relatively quiet and noise free band.

The radio can be an un-modified voice grade transceiver or our own custom high speed unit through which the operators display communicates data with the base station.

A standard voice grade radio will operate at 2400 BPS, our custom unit will send data at 8000 BPS.

A roof mounted 1/4 wave antenna is provided along with the radio set.

Description of Monitoring Functions

The acquisition of sensor data for real-time protection, long term trending, and diagnostics are all features of the system. Each function is described in greater detail in the following paragraphs.

Real Time Protection

The on-board system will sample the sensors and transducers at variable scan rates from 1 second to 10 minutes depending upon the criticality of the point sensed, the base time constant of the physical process, and the need for diagnostic data.

The on-board computer provides for a variety of different alarm conditions to be designated, these are:

a) Traditional set-points

b) Alarms dependent upon one other parameter

c) Time dependent alarms

d) Time delayed alarms

e) Alarms generated from multi-variables through calculations

f) Digital On/Off alarms.

Statistical Bar Charts

The on-board computer will be collecting sensor data and compacting the data by means of statistical analysis. A typical example of such a reduction used for ENGINE OIL PRESSURE but similar for all other analog signals is as follows:

During operation of the vehicle, engine oil pressure will be sampled at one second intervals.

The pressure readings will be slotted into intervals such as 0-10 Psi, 11-20 Psi, 21-30 Psi, etc. to the maximum pressure expected.

The duration in minutes or hours that the pressure resided in each interval will be calculated for display.

As well, the minimum, mean, maximum and number of points analyzed will be calculated, transmitted, and displayed.

Thus, each analog sensor (oil pressure in this example) will be displayed as a bar chart or histogram at the base station.

Predictive Diagnostics

Predictive diagnostics are included in the system for those parameters that can be related to equipment life. Typical of such points are the following:

* Brake or clutch wear
* Oil/hydraulic pressure trends
* Engine misfiring and/or compression variance
* Snap acceleration test
* Crankcase ventilation pressure.

Raw Data Files

The collected data from the equipment can also be output in tabular form. Where special sorting for maintenance or operations reasons is desired, the DBASE III format allows the use of LOTUS, statistics packages, and a variety of graphics and other data base packages.

This feature allows the customer to manipulate the data and to create custom reports, graphs, or analysis without our involvement.

Base Station

The base station computer system can operate as a stand alone system or as a remote terminal connected to an existing mainframe system. The base station to be provided is an IBM AT clone.

Operations Reports

Production monitoring is readily achieved using combinations of the sensors that have been installed for mechanical monitoring. The operator of the machine can be given numerical codes to enter that will enable availability to be automatically calculated, the time taken to repair, frequency of repairs, etc. Below are the standard reports that are included in the system.

a) Active Time

This function is readily derived from vehicle motion. Essentially an operator signs on via a personal ID code. The system than sums the time that the equipment spends actually moving during the period between sign on and sign off.

b) Idling Time

Idling time is the sum of the time that the equipment spends with the engine running but with no vehicle motion. As above, it is accumulated between sign on and off.

c) Off Time

Off time is calculated as the sum during a 24 hour period of the times that a machine is off or not running.

d) Number of Cycles

The number of complete machine cycles (load, haul, dump) that have been performed during a given shift can be determined and a report or bar graph generated from the data.

To accomplish this a 'signature' of a cycle must first be defined. Such a signature is a

combination of wheel movement, steering actions, engine RPM, and hydraulic activation.

A total daily production report can be generated from the accumulation of weight data based upon the machine cycle definition.

f) Special Codes

To provide better data to operations regarding the efficiency of the overall machine or fleet of machines, a variety of operator entered codes can be used to describe the status of the equipment during the day. For example, downtime can be entered as a code that relates to a specific failure.

Thus code 11, could define "hydraulic hose failure", code 12 track bogie problem, etc.

These codes then become time stamped and can be reported in bar graph form or analyzed through a DBASE routine.

This technique enables equipment managers to build up an accurate database for determining efficiency, equipment reliability, equipment warranty claims and other pertinent factors.

3.3 Caterpillar

The following information is quoted from material provided to Wenco by Caterpillar on their truck payload measurement system:

The Truck Payload Measurement System is primarily used to measure, display, and record the weight of material (payload) being hauled by off-highway trucks. This information is useful in monitoring the productivity and activities of trucks in a mining application.

In addition to payload information, several other items are recorded for each cycle by the payload measurement system for later access and use by mine management. A few of these items include idle time, travel time loaded and empty, loading time, and traveling distances loaded and empty. From this data, a number of characteristics of the loading cycle can be determined by the mine management. In order to access this information, the truck payload measurement system provides a serial communications port to the user. The user can connect a compatible device into this port and extract the data.

Components

The Truck Payload Measurement System consists of the payload measurement control (PMC) electronic module, the payload operator's display (POD) electronic module, four strut pressure sensor units, left and right external loading indicator lights, and the harnesses. In addition to this hardware, the bed-raise switch, the transmission speed distributor, and the neutral start control (standard hardware on the truck) are utilized as input to the system.

The "brains" of the system is the payload measurement control (PMC) module. It reads the vehicle status inputs, processes them, records the results, and controls the outputs. The PMC module is located behind the operator's compartment.

The vehicle status inputs are:

1. The bed raise switch - this signal tells the PMC when the body is being raised and the contents of the body are being dumped.

2. The transmission speed distributor - this signal provides vehicle speed to the PMC. The PMC knows when the truck is stopped or moving. It also knows the speed of the moving vehicle. The transmission speed distributor is located inside the center console in the operator compartment.

3. The neutral start control - this signal tells the PMC when the transmission is in neutral. The neutral start control is located on the front wall inside the center console in the operator compartment.

4. The four strut pressure sensors - each of these four sensors provide the payload measurement control with a signal that is directly proportional to the pressure in the respective strut. The strut pressure sensor is mounted at the top of each strut cylinder.

By having these signals as inputs, the PMC can process this information and monitor the truck as it goes through its entire cycle. A typical cycle is defined as:

1. Roading empty to the loading site.

2. Loading.

3. Roading loaded to the dump site.

4. Dumping.

Data obtained from each cycle is retained by the PMC in a non-volatile memory, allowing the user to extract this information at his leisure. The memory in the PMC allows data (up to 890 cycles) to be stored indefinitely, or until the information is extracted by the user. When extracted the non-volatile memory is erased and ready to begin storing new data.

A non-volatile memory is a term given to an electronic memory device that has the capability of saving its contents upon the removal of power from the system.

Outputs from the PMC are the two vehicle displays; the payload operator display (POD) in the cab, and the external loading indicator lights. The POD is mounted in the dash. It consists of three-digit liquid crystal display (LCD) used to indicate the weight of the load in the body. The weight can be displayed in either English or Metric tons. The dash mounted display also has two light emitting diodes (LED), (one red and one green). These two LED's duplicate the activity of the external load indicator lights. They also indicate a fault has occurred. The external load indicator consists of two sets of lights. Each set has one red and one green light. There is one set of lights on the left and right sides of the truck. These lights are used as indicators to the loader and truck operators that:

1. A load is detected.

2. The maximum load is detected.

Calculating the weight of material in the body of the truck is based upon measuring the difference between empty and loaded strut pressures. Thus, the payload calculated, displayed on the POD and recorded in the non-volatile memory is the true payload, neglecting fluctuations in the weight of fuel and dirt accumulated on the body and frame.

Once the vehicle begins moving, the PMC starts keeping track of the time and speed. The distance traveled can now be calculated when the vehicle comes to a stop. This data is retained in a temporary memory until completion of a cycle.

Bed-raise switch actuation tells the PMC that one cycle has ended and another is beginning. When the bed-raise switch is opened, this indicates that the operator is raising the body and dumping the load. For the first empty loading period to the loading site at the beginning of a shift, it is assumed by the PMC that the bed is empty and that this roading activity is the start of a load cycle.

After arriving at the load site, positioning the truck for loading and coming to a stop, the PMC will know loading has

begun by a sudden and dramatic increase in pressures on the struts. Strut pressures are measured and compared to the calibrated empty pressure. This is done each time the truck is topped and empty. Now the empty pressure used to calculate the payload are adjusted for changes in the truck tire weight due to mud build up, fuel consumption and temperature effect on components.

If a truck is partially loaded and moved less than .1 mile and then is fully loaded, the PMC will record only as one load. If the truck is moved more that .1 mile the loading is disabled.

When the truck moves away from the loading site, the external load indicator lights, and the POD light emitting diode are turned OFF by the PMC. The value shown on the POD is saved into temporary memory as the payload weight. This number is retained on the POD until the load is dumped. Time and speed are once again monitored as the truck roads from the load site to the dump site. Both are saved in temporary memory when the truck arrives at the dump site. The truck is positioned to dump the load. The operator pulls the dump lever. The bed-raise switch signals the PMC that this is the end of the cycle. Five seconds after receiving this end-of-cycle signal, the POD clears the payload value just dumped from the POD digital display. This officially flags the operator that the cycle is complete and a new one is beginning.

All information obtained during a completed cycle is moved from temporary memory and placed in non-volatile memory. Before moving, the temporary data is "protected" from corruption. That is, additional information is added that allows the PMC to check for any loss of integrity before transmitting to the user over the communications link. This additional information is then stripped off by the PMC before transmission, such that the data is intact and accurate when received by the user.

This completes the operation of one typical load cycle. Up to 890 such cycles can be recorded before the non-volatile memory is filled. If the user does not extract the data at this point, all additional cycles are ignored and go unrecorded. It should be noted that the operator receives no warning of this condition. The display and lights continue to function in the normal fashion. Therefore, a retrieval schedule must be set up and followed to prevent the non-volatile memory from overflowing.

3.4 Interactive Sciences, Inc.

Interactive Sciences is working with P & H to produce a bucket weighing system for their rope shovels. The company is in the final stages of developing the product so very little information is available.

3.5 Philippi-Hagenbuch, Inc.

Philippi-Hagenbuch produces a data acquisition system called Onboard Data Acquisition System (OBDAS). The system was tested at the Gregg River Mine in Hinton, Alberta under a cooperative demonstration and evaluation project on two Euclid R-170 trucks from January to November 1987. The following description of the Obdas system is quoted directly from the report "Demonstration of the On-board Data Acquisition System (OBDAS)", by G.B. Gould, B. McConechy, and V. Srajer, December 15, 1987:

DESCRIPTION OF SYSTEM COMPONENTS

Central to the OBDAS system is an onboard microprocessor, used to manipulate input signals and provide output essential for equipment performance monitoring. The processing unit used by the system is a Motorola 68HC11, capable of receiving both digital and analogue input signals and time relating these signals using a built-in clock. Presently eight digital and eight analogue signals are being sent to the processor, with capacity to handle 24 more of each type of signal.

OBDAS's primary onboard sensing function is weight or payload monitoring. It is through this function that the most direct benefit, through cost savings, can be realized by a mining operation. The OBDAS weighing system (described for Euclid R-170 trucks) features four load sensors installed on the truck frame and forming the contact area for the box rails. Each load sensor consists of a 9" wide by 79" (front) or 83" (back) long urethane jacketed flexible hose that is partially filled with oil. Each hose sits in a base plate channel assembly that has been mounted directly onto the truck frame. The ends of the hose are sealed shut with a clamp, with one end having a fitting for a 1/4" diameter nylon hose that leads to a pressure transducer. The pressure transducers, one for each load sensor, are mounted outside the cab of the truck and provide a voltage signal (varying with pressure) to the microprocessor. A floating cap channel with an inside contact plate having a specific area sits on top of the hose assembly. By applying the area of the contact plate to the pressure created in the hose by the truck's load, the weight being carried is produced.

Second to knowing what weight is being carried by the truck, is the information required to complete a time study of each haul cycle; including times for loading, travel empty, and waiting. This is achieved by combining the built-in clock feature of the processor with input signals received from additional OBDAS hardware.

Travel/non-travel time and direction of travel are gained using a transmission directional (forward-neutral-reverse) switch. The reverse signal is picked up by using the truck backup alarm power signal, the neutral signal from the truck neutral safety switch power signal and forward when there is no reverse or neutral signal.

The start/end point of the haul cycle is picked up from the dump switch; a mercury activated switch mounted near the pivot point of the dump body. An input signal is received from this switch when the truck box is raised for dumping, indicating completion of a haul cycle.

Travel distance is determined by a proximity switch which serves as an odometer by sending a signal to the processor at each complete tire revolution. The proximity switch is mounted on the left front wheel of the truck and consists of a sensing oscillator, a solid state amplifier and a switching device. Proximity switching is achieved when a metallic object (target) passes through the sensing field, representing one tire revolution. This changes the internal impedance of the oscillator, giving a signal to the microprocessor. By applying tire circumference to the number of revolutions (sum of signals received from the proximity switch), the distance travelled in each gear direction is determined.

To have the information required for a complete analysis of a haul segment, the hardware installation includes an inclinometer for developing haul road profiles. A varying voltage signal, based on the slope the truck is on, is sent to the microprocessor from the level indicator. The inclinometer must be activated through the processor to receive output (slope indication is not monitored continuously); with output provided at every one degree change in road grade.

The remaining input to the microprocessor is entered by the truck operator through the processor key pad. This input includes an operator code number (corresponding to the employee number) and a combination code for the loading unit and dump destination that the truck is assigned to. The operator code (3-digit number) is entered at the start of the shift or when there is a change of operator on the truck. The loader/destination code is changed whenever there is a change to these assignments, and is replaced with an operating delay or maintenance code when the truck goes

out of production. Through this coding, the ability to report productivity on an hourly basis and equipment utilization is achieved.

Manipulation of the incoming signals and information output by the OBDAS microprocessor has been developed to provide real time monitoring onboard the truck and to remote locations.

Output signals for onboard viewing include a LED display on the front of the processing unit that provides a reading to the truck operator of actual load weight (tons). Through the key pad the date, time, and a check for coding (operator, loader/destination) can also be displayed.

To give the loader operator an indication of load status, a series of loading lights and imbalance lights are mounted on the truck (both sides). The loading lights consists of five lights; a green light indicating one or more bucket passes required, three amber lights indicating portions of a bucket required, and a red light indicating that the rated payload has been reached. The fore-to-aft imbalance lights give an indication to the loader operator if the next bucket should be placed towards the front or back of the truck to give a balanced load.

Additional onboard output includes a printer that is used as backup for data collection, gathering road profile information when required, and running diagnostic checks on the system.

Real time remote monitoring is achieved through a radio frequency (RF) data link (built into the processor) to the VAX 11/750 computer located in the engineering/administration office, 300m to 3000m away from the truck operating location.

Input signals to the microprocessor are compiled and output, either to internal storage or to RF transmission, whenever there is a change in the truck transmission position, as signalled by the forward-neutral-reverse directional switch. The line of data compiled at this point includes truck number, clock time, load weight in tons, transmission position, length of time spent in this position, and distance travelled in this position. The dump signal indicates the end of the haul cycle, with the raw data output at this time indicating cumulative time and travel distance since the last dump signal was received.

3.6 Pit Control

Pit Control is a new company which recently acquired the right to produce and sell the BEPAL shovel weighing system developed by Bucyrus-Erie.

BE originally installed the BEPAL system on 17 shovels, of which nine are still in the field. Technical difficulties resulted in disuse of the system at most mines. Pit Control has developed and is now distributing a hardware and software upgrade to some of the mines where BE originally installed BEPAL.The system is reported to be working very well at one of the Kerr-McGee coal mines in Wyoming.

The system, we understand, currently works only on BE rope shovels. The approximate cost of the system with a radio telemetry system is $US 85,000, and $US 70,000 without.

3.7 Ropec Industries Inc.

The Ropec Engine Protection System provides immediate warning and a sequenced engine shutdown in emergency situations or when engine problems are identified. The system consists of a controller, annunciator, battery relay, and uses a network of sensors.

Engine parameters are monitored through the sensors. Signals received from the sensors are analysed by the controller and a logical sequence of events leading to engine shutdown is initiated. In response to a signal from the controller, the annunciator visually and audibly warns the operator of the detected fault. If the fault is a non-emergency, the over-ride button may be used to give the operator time to move the equipment to a safe location before engine shutdown.

Engine shutdown is logically dependant upon several conditions. If the vehicle is in motion, the motion override feature prevents engine shutdown until speed is reduced to between 5 and 10 m.p.h. (adjustable). If the engine is in a stopped vehicle, shutdown occurs immediately in emergency situations and after 15 seconds in non-emergencies.

The high current battery relay is activated by the controller to produce an electrical disconnect as the final step in the shutdown sequence. This reduces possible short circuiting and resultant fire hazard while the machine is parked. The battery remains isolated until the vehicle electrical system is re-energized by pushing the "power button".

Although the system is designed for a variety of industries using heavy machinery, some open pit mines have these units installed and are very pleased with the results.

3.8 Unit Rig and Equipment Company

Unit Rig produces a vehicle monitoring system called Unipars. Unipars monitors engine parameters such as pressures and temperatures, and electrical parameters. There is also a means of measuring payload, but on their diesel-electric trucks only. They have not done payload weighing on their mechanical drive trucks.

All parameters are examined only when the truck is drawing maximum horsepower. At that time, a "snapshot" of all the points is taken.

The data is accumulated over a 24 hour period and downloaded into a battery-backed RAM cartridge. The cartridge data is fed into an IBM-PC which prints the data. There is provision for radio telemetry of the data through an RS-232 port. However, they have not used telemetry to date, and they have no plans to do so unless a customer asks for it.

There are 20 Unipars units installed in 7 or 8 locations around the world.

3.9 Wabco

We were advised by a Wabco representative that the company is scheduled to introduce a monitoring system toward the end of 1988. It will record both production information by load weight, and mechanical information. A data radio system may be available as an option. No further details were made available.

3.10 Wenco International

3.10.1 Overview

Wenco International Mining Systems Ltd. produces a microcomputer-based system called Production Monitor and Control System (PMCS).

PMCS is a computerized truck/shovel management system designed to meet a wide range of needs in open pit mines. Production and operating information in real time is sent from equipment in the mine to a base computer, where it is displayed and stored.

The displayed information can be used by production staff to make decisions on equipment allocation as the shift progresses. The data collection process can be unmanned, or manned from time to time to track progress and make changes as required. With the dispatching option, the computer automatically calculates the dispatch assignment for the truck then sends the instruction to the driver through the data radio link.

The system consists of Mobile Data Terminals (MDT's) in the trucks and shovels, a data radio communications link, and the MONITOR computer which displays and stores the information. The optional dispatching function works with MONITOR. Another computer is used for the MANAGEMENT INFORMATION SYSTEM (MIS) for longer term data storage and generation of graphs and reports for management.

The MONITOR computer provides mine staff with production and operating information as the shift progresses, and produces detailed shift reports and turn-over sheets. The MIS computer stores information on the fleet performance and production for later analysis and summary reporting through graphs and tables. Equipment assignments are made by staff, rather than by computer.

With the automatic truck dispatching option, the system uses a software program that minimizes equipment waiting time. Current product blend and the target blend are displayed so staff can make adjustments to the shift plan as required.

3.10.2 Data Collection

Production and operating data can be collected by either:

1) Manual entry by the operator through the Mobile Data Terminal (MDT) keypad, or

2) Automatic location recording through the use of location beacons along the roadside.

The choice of methods is generally based on the preferred management style at the mine.

The trucks and shovels are equipped with industrial quality mobile data terminals (MDT's), which incorporate a keypad, bright LED display, microprocessor, 64K expandable memory, power supply, modem, data radio and external data input, all in a single rugged box.

Truck drivers and shovel operators report their status using the MDT keypad by touching the appropriate key upon completion of each phase of the cycle (ARRIVE AT SHOVEL; START LOADING; FINISH LOADING; DUMP). Delay codes are entered this way as well. If a driver's shovel or

destination assignment is changed, he can key this directly into his MDT. The MONITOR computer will automatically record the change, and correctly record the new production change.

3.10.3 Data Radio System

A dedicated data radio channel is used to transmit the data from the MDT's to MONITOR computer. PMCS uses a protocol and modulation scheme specially developed for application in open pit mines.

The communications controller receives signals from the truck/shovel MDT's. It decodes the information, performs error checking and data verification, then sends the data to the MONITOR computer.

The data radio system will not affect operation of existing voice radios.

3.10.4 Monitoring Production and Operating Information

The heart of PMCS is the microcomputer that runs the MONITOR program, which receives its data by radio directly from production units in the mine. It displays a wide variety of performance and efficiency factors, and stores the information for later reporting and analysis.

The displayed information can be referred to from time to time, to monitor the shift progress. Significant productivity increases have been achieved by operators using the information from the PMCS MONITOR screen to run the truck/shovel operation. The system does not have to be attended by a full time operator.

A second microcomputer runs in parallel with MONITOR on a "hot standby" basis in the event of a temporary hardware or software interruption.

The current status and location of the equipment are indicated on a computer screen along with up-to-the-minute production statistics. These include:

- Product blend
- Current equipment operating status
- Production this shift by material type
    - Production this shift by machine
    - Production this shift by location
    - Operational indicators such as delays and waiting times
    - Stockpile levels

At the beginning of the shift, all assignments will appear on the MONITOR screens as they were at the end of the preceding shift. There are four primary screens providing status information, and seven secondary screens used to make and change assignments, and to control PMCS functions and tables.

The four mine status screens are:

1. Ore Fleet Status
2. Waste Fleet Status
3. Ore Production
4. Waste Production

Ore Fleet Status gives the location of each loading unit and the trucks that are currently serving them. Also provided are:

* current production this shift
* forecast end-of-shift production
* loader waiting times
* truck waiting times
* target blend
* actual blend

In addition, this screen shows where each truck is in its cycle:

1. Hauling loaded
2. Returning empty
3. Waiting to load
4. Loading
5. Delayed
6. Down

Specific types of delays such as fueling stops, lunch breaks, tire checks and the like are entered by the truck or shovel operator through the MDT using delay codes. These are accessible through MONITOR.

Waste Fleet Status displays the same type of information as the Ore Fleet Status screen.

Ore Production displays the tons of ore moved during the shift, including sources and destinations. The planned and actual blends are updated as each load is dumped, providing the capability to divert in-transit haulage units for fine tuning. Loaded trucks and the product they are carrying are identified on the Fleet Status screens.

Waste Production provides similar information as it applies to overburden removal. The system can accommodate different types of waste and rehandle activities if such detail is required.

The seven secondary screens consist of a variety of assignment and control screens, including a 'main menu' from which all functions of Monitor are accessed.

At the end of shift the MONITOR program will perform a series of tasks designed to complete the record of this shifts activities, and assist oncoming staff in organizing their shift. This activity results in a turnover report, a shift report and data files for transfer to the MIS computer. The turnover report is used by oncoming staff to understand present equipment assignments and to assign crews to their tasks. The shift report summarizes shift results for line staff, giving the information referred to above, plus:

- Productivity by fleet and unit
- Availability
- Utilization
- Location and status of each equipment unit.

3.10.5 Dispatching

The dispatching software calculates the assignment for a truck once the DUMP key has been touched, or optionally when the truck passes a location beacon as road branch is approached. The program will send the truck to the location which will result in the minimum amount of waiting time.

The computer transmits the dispatch assignment via data radio to the truck, where it appears on the display of the mobile data terminal. An audible beep is produced to alert the driver of the new assignment.

Dispatch instructions issued by the computer are also shown on a message line at the foot of the MONITOR status screens as they are transmitted to a truck's mobile data terminal.

3.10.6 Management Information System

The Management Information System (MIS) microcomputer is generally located in the mine office where it is accessible to mine management and engineering personnel. The MIS computer compiles and summarizes key information collected by the MONITOR computer.

The MIS system is menu-driven and simple to use. Information is available either visually on the full-color screen, or through printed color graphs and reports.

Through the use of the control function in MIS, mine management can control events and activities in the pit. The way mining is carried out is directly controllable by specifying where equipment can work, dump locations, and many other parameters.

4. DISCUSSION AND RECOMMENDATIONS

4.1 Discussion

Equipment information systems cover a wide spectrum of activity and are of use to different persons in the mine organization. These are summarized in the table below:

	USED BY:			
MONITORING FUNCTION	Operations	Mine Planning	Maintenance	Equipment Operator
Production:				
- Real-time	X			X
- Historical	X	X		
Vehicle:				
- Vital Signs	X		X	X
- Comprehensive		X	X	

The recommendation of a single product for field testing is not possible for the following reasons:

1. Many of the products in this category have functions that overlap in different areas.

2. There are several groups of users to be addressed, and as the table above demonstrates, no single product meets everyone's needs.

3. As a result of the user surveys and review of the literature during this phase, we observed that the needs of the maintenance group have not been adequately addressed as part of the terms of reference.

4. The integration of all the systems studied presents technical difficulties related to data radio protocols and throughput. In general, information required in real time should not be integrated through the data radio link with information required on a periodic batch basis.

In light of this, the following strategy is recommended:

i) Test products that integrate readily both technically and with regard to the end use of the information. This compatibility should address the following areas:

   a. Data radio communications
   b. Whether the information is required in real time or less frequently
   c. End users of the information
   d. Availability of appropriate technology
   e. Needs of the mines as expressed in the user surveys.

ii) Conduct further studies on systems directed at the maintenance group of the mine, specifically comprehensive vehicle health monitoring.

4.2 Recommendations

4.2.1 Vehicle Health Monitoring

In the vehicle health monitoring area, the following suppliers offer products:

Advanced Electronic Systems Ltd.: Emphasis on predictive monitoring.

Ropec Industries Inc.: Emphasis on vital signs monitoring

Unit Rig: Monitors engine parameters on Unit Rig diesel electric trucks only; readings taken only at the point of maximum horsepower usage in haulage cycle.

Wabco: Plan to introduce mechanical and weight monitoring late 1989

As discussed earlier, vehicle health monitoring can be broadly classified into two broad categories: 1) vital signs monitoring, and 2) comprehensive monitoring.

Vital Signs Monitoring

Since vital signs monitoring information is required in real time and is useful to production personnel, we recommend that it be integrated with the real time production monitoring information.

The Ropec Industries Inc. Engine Protection System is recommended for testing from this group. The demand for this kind of product has been demonstrated by mine

operators, and several systems are in use or being installed by the mines.

The AESL system has interesting possibilities, but the demand has not been as strongly expressed by the mining companies. The system is currently being tested at an underground mine in the Sudbury area under National Research Council funding, so we recommend that this project be monitored for possible future application in open pit mining.

The Wabco and Unit Rig products are (or will be in the case of Wabco) specific to the trucks manufactured by these companies. It is our opinion that these products will serve a real need. However, for the purposes of this program, testing of products is not recommended at this time because of the truck fleet composition at the participating mines, and because one of the products is not yet available.

Comprehensive Monitoring

Comprehensive monitoring information is required for component management and predictive maintenance. The volume of information generated by these systems is much greater than for vital signs monitoring, and it is not required in real time.

We did not envision studying comprehensive monitoring as part of Phase 1 because of the production-oriented nature of the project. However, comments received from mine operators suggest that comprehensive monitoring should be examined in greater detail. We recommend that this important area be studied further.

Comprehensive vehicle monitoring does not readily lend itself to integration into the truck/shovel production monitoring system for two major reasons:

1. The end user of the information is in the maintenance group.

2. The data radio system requirements for short-message real time applications is different than for long-message batch data.

Accordingly, this study should be carried on in parallel with the integration components. Rather than delay the continuation of the project as a whole, Phase 2 should proceed on the planned schedule. To advance the comprehensive vehicle monitoring portion of the project to the same point as the rest of the project, we recommend that the "Phase 1 and 2" tasks for comprehensive vehicle monitoring be performed in Phase 2.

The estimated cost for including comprehensive vehicle monitoring in the project is difficult to establish at this time. The following is a rough preliminary estimate which will be refined as the project proceeds.

1. User survey	$20,000
2. Further review of available technology	10,000
3. Conceptual system design	10,000
4. Budgets, subcontractor selection, and reports	20,000
Total Preliminary Estimate	$60,000

4.2.2 Payload Monitoring

Payload monitoring can be achieved either at the shovel or on the truck. The following systems are available, categorized by where the weighing is done:

Truck Weighing:

Caterpillar

Philippi-Hagenbuch, Inc. - OBDAS

Unit Rig - UNIPARS

Wabco (future)

Shovel Bucket Weighing:

ACET - SPARC

Interactive Sciences

Pit Control - BEPAL

Selecting a payload monitoring device is complicated by the following:

1. The shovel weighing devices are all made for rope shovels.

2. Most of the truck weighing devices are designed specifically for a particular manufacturer's truck.

We do not recommend that shovel weighing devices be tested under this project at this time, because they are all designed for rope shovels only. Both mines participating in the field testing phase use hydraulic shovels, so rope shovel weighing devices will not meet their requirements. Furthermore, there is a trend toward using hydraulic shovels in the mining industry. There are no hydraulic shovel payload monitoring devices currently available.

The selection of a truck payload measurement system for trucks is made difficult by the fact that most of the systems are truck brand specific, and most mines have a mixed fleet of trucks. The only system which is not associated with a particular truck manufacturer is the OBDAS system, which has already been tested through another CANMET project. A further difficulty is that it is not applicable to all truck frame designs.

We recommend the testing of the Caterpillar system for the following reasons:

1. Both mines participating in the project use Caterpillar trucks.

2. The system is currently used in mines so is logical for inclusion in the integrated system.

3. It is reasonably representative of such systems and meets the requirements of mine operators.

4. The only other logical candidate, the OBDAS system, has already been tested under a separate project. Testing the Caterpillar system provides the opportunity to expand the industry's knowledge.

4.2.3 Production Monitoring and Control

As a base for integration of these systems, the WENCO INTERNATIONAL Production Monitor and Control System (PMCS) is recommended because:

1. The software for communications, processing, displaying and reporting is already well developed. The integration of the information from payload monitors and vital signs fit in well.

2. PMCS has an advanced data radio communications system developed for open pit mines. The protocol was designed to accept information from other sources.

3. PMCS is currently being successfully used at the two operating mines participating in the project.

4. WENCO INTERNATIONAL has the mining experience and in-house expertise to do integrate the systems.

5. PMCS is a proven product that is applicable across a wide range of mine sizes and types, so the benefit of the work to the mining industry will be maximized.

APPENDIX VI

COMMUNICATIONS, DETAILED ANALYSIS

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1. INTRODUCTION

This report addresses the data transfer system for an integrated truck/shovel operating and management system for open pit mines. Its purpose is to discuss the objectives to be achieved by the data transfer system, review the available technology, and to recommend a preferred option.

Computer-based truck monitoring and dispatching systems created the first real requirement for mobile data communications in mines. Recently, equipment information systems and mobile equipment location devices have either become available or are proposed for open pit mines. Equipment information systems provide production data such as payload weight, and mechanical data such as engine fluid pressures, levels and temperatures. The objective of a data transfer system is to deliver this information from moving vehicles to a base computer. These requirements are discussed in detail.

The review of the available technology is covered in two parts. First, an overview of data radio communications terminology and specifications is provided. This is necessary to allow the reader to understand the limitations and constraints that are placed on a system by the mining environment and proposed applications. Second, applicable data transfer systems are reviewed.

Finally, the preferred option is discussed in light of the varying requirements and constraints imposed by the mine operation and environment.

2. SYSTEM OBJECTIVES

2.1 Integration Components

Data from the following components of the operating and management system are being considered for integration through a common data radio system:

A. Mobile Equipment Location System

This information can be given in several ways, and is transmitted from the mobile equipment to the base. The length of this type of message is very short, and can consist of as few as two characters for a two digit location identification number. Typically, the message would be seven characters or longer to include the location identification number, truck identification number, and other protocol information. This information is required real time if it is to be used for dispatching. For production monitoring purposes, it is preferable to have this information real time so that the operations staff can observe the information and act upon it as the shift progresses. In some limited production monitoring systems, the information is stored on a shift or day basis and is used later for summary purposes only.

Among the methods of location monitoring are:

i) Navigation equipment which can provide continuous location monitoring.

ii) Roadside marker beacons which transmit a location code to passing equipment.

iii) Operator input through a mobile data terminal keypad. This would typically be used for production monitoring and dispatching. A truck's location within the haul cycle is keyed in by the operator (Arrive at shovel, Start loading, Finish loading, Dump, Delayed, Down, etc.). This often provides adequate information for a dispatch computer to assign the truck efficiently. Status information such as delays or downs can be indicated through operator input as well.

B. Dispatching

This message from the base computer to the trucks is very brief, containing only a truck ID and the assigned destination. This information is required real time.

C. Equipment Information System

Vehicle monitoring information can be divided into two categories:

i) Vital signs information, which reports critical conditions such as overheating, overspeed, and oil pressure drop. This information is of course of direct use to the driver, but may also be used to automatically shut down the engine or take other action, for example if the truck is sitting unattended with the engine running. Some mine operators may want vital signs information to be made immediately available to the operations office, such as the automatic shut down of a vehicle which has been idling unattended. This information should be transmitted to the operations office immediately.

ii) Vehicle health monitoring information, which is information collected on the mechanical health of the vehicle over a period of time. This data collected from various sensors is stored in an on-board data base. The data base information can be downloaded by hard wire connection to a portable computer, through removable memory storage devices, or through a data radio link. The information is not required real time, and could be sent thorough the data radio system on a batch basis once per shift or once daily. The use of a radio system for this application is more of a convenience than a necessity. However, without a radio system, health monitoring systems could fall into disuse when changing priorities make manpower unavailable for physically collecting the data off of each vehicle.

2.2 General Requirements

Reliability

Electronic equipment for use in mines must be able to withstand significant vibration and extremes in temperature. Many mines do not have staff specially trained in electronics, so the equipment must have a low failure rate. Broken down equipment will often go unrepaired unless procedures are in place to deal with repair on site or replacement by the supplier.

Military standards are often cited as appropriate for equipment to be used in the mining environment. While military specifications may be appropriate, the test of time and experience is probably more valid, particularly for products that have gone through several stages of evolution in a mine. Designing and testing to military specifications adds

a significant price premium to a product, and may not add to its reliability.

Abuse

Abuse of the equipment can be a problem, particularly if the system is of the type that uses operator input rather than being automatic. Protection from vandalism is almost impossible to design for, and is best dealt with at the personal level through a carefully thought out training program where the equipment operators are involved throughout the whole process and are shown how and why the information is being collected and used.

Cost

The data radio communications portion of a system cannot be analysed on a stand alone basis because it is an integral and essential part of dispatching, location monitoring and equipment information systems. The data radio portion of the system must not push the overall system price over a financially justifiable limit.

The overall cost of the equipment must of course be in line with the real or perceived benefits to the mine. A payback period of one year or less is generally attractive to any mine operator. However, the financial benefits can often be difficult to ascertain in advance even with the use of simulation models.

3. TECHNICAL OVERVIEW

3.1 General

Information from digital devices is in binary form, where a one is generally represented by a positive DC voltage level (generally 5 volts) and a zero is represented by a zero voltage level. Communications between devices connected by a wire line within a local area can be done directly, since the positive and zero voltages can be sent over the wire. Although telephones are directly connected by wire, the telephone system is an analog medium, so DC voltages cannot be transmitted directly.

Radio is also an analog medium. The DC pulses from digital equipment must be converted to a form that can be transmitted. A modem is used to convert the DC pulses into one of two audio frequencies (often 1200 and 2200 Hertz) to modulate the radio frequency carrier (typically at a frequency around 150 MHz for VHF and 450 MHz for UHF). These audio tones vary the frequency of the carrier, which is detected by the receiving modem. The receiving modem converts these tones back into DC pulses which can be again understood by a computer.

Most communications between computers is over wire links, so many of the conventions and standards used is data radio communications came from the computer industry.

The basic system structure is shown in Figure 1.

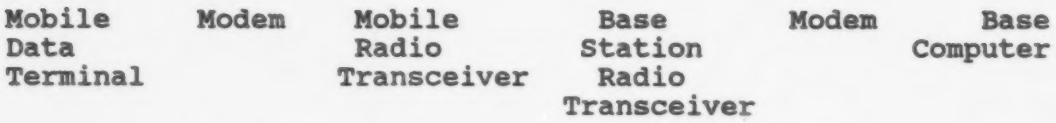


FIGURE 1

3.2 Modulation Schemes

The modulation scheme deals with how the information is superimposed on the radio frequency carrier.

Most systems for data radio communications use frequency modulation (FM) rather than amplitude modulation (AM) because of FM's superior noise immunity.

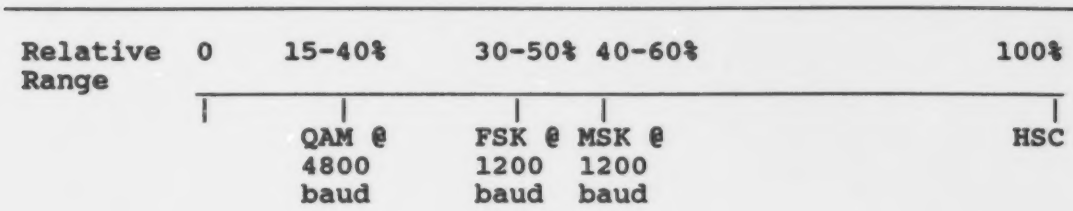
The most common method of modulating the carrier is with frequency shift keying (FSK), where a zero bit is represented by one frequency (1200 Hz) and a one bit is represented by a second frequency (2200 Hz). A variation of FSK is minimum shift keying (MSK), also referred to as fast frequency shift keying (FFSK), which uses audio signals at 1200 and 1800 Hz to represent the two bit states. Data throughput is a function of bandwidth, and since MSK requires less bandwidth, it can operate at a higher throughput for a given bandwidth than FSK.

Bit rates of up to 9600 bps can be achieved by bypassing some of the radio transceiver circuitry and using other techniques. This requires re-certification of the radio equipment. Currently such high bit rates can be achieved only for base to mobile systems, and have a very poor signal-to-noise ratio and accordingly comparatively poor range.

Many earlier data radio communications schemes were based on the Bell 202 modem scheme, which is a 1200 bits per second (bps) FSK scheme. This scheme was not developed for radio but rather for wire line communications between computers. Accordingly, it does not take into account the problems faced in radio communications such as multipath interference and impulse noise.

A recently developed signalling format is the Hexadecimal Sequential Code (HSC), which was developed specially for radio. It is analog in nature and is almost totally immune to radio multipath and impulse noise interference. HSC consists a discrete tone (one of 16) every 33 mS. The HSC format provides 99.9% decode probability at 0 dB signal to noise ratio, which is many times better than FSK schemes. The tradeoff for this high fade and noise immunity is a raw bit rate of approximately 400 bps.

A major advantage of HSC is that it has far greater range than FSK and MSK schemes for the same RF power output. An approximate comparative graph given below demonstrates this. It should be noted that these comparative figures are generalized and could change significantly under different conditions. The figures given below approximate typical field performance with application-specific forward error correction - 50% redundant.



Comparative Range

Note: Except for HSC which has high immunity to noise, range could quickly drop to near zero in high impulse noise situations.

MSK is better than FSK in signal-to-noise ratio (3 to 5 dB) because it occupies only 0.6 of the bandwidth of FSK. This translates into a range improvement of approximately 15%.

3.3 Protocols

A data radio signalling protocol is the set of rules by which two communications devices talk to each other. A protocol defines, for example, the position and meaning of certain characters in a string of data.

Protocol efficiency is a measure of the percentage of message time actually devoted to the message itself.

There are several thousand proprietary protocols. Many of these were developed from the computer communications field. A significant number of protocols are adaptations of one another, and were developed to suit a particular requirement.

There are several hundred protocols which are in the public domain, including computer protocols.

The selection of a data exchange protocol is based on a number of factors, including required speed, condition of the communications medium, whether the messages are very short or very long, and the frequency of messages. The selection of a particular modulation scheme sometimes implies the use of a particular protocol, as in the case of the Hexadecimal Sequential Code (HSC) scheme.

3.4 Frequencies

The radio frequency carrier can range from as low as 20,000 hertz (20 kilohertz) to over 20,000,000,000 hertz (20 gigahertz). One hertz equals one cycle per second.

Ideally, the selection of a particular carrier frequency is based in part on the propagation qualities desired and the information throughput needed. In general: 1) the lower the frequency, the greater the distance covered, but the greater the interference; 2) the rate of information throughput increases with bandwidth. The selection and use of radio frequencies, however, is tightly regulated worldwide and only certain frequencies and modulation schemes are available.

The Canadian government agency which controls the assignment and use of radio frequencies is Communications Canada. The generally available frequency ranges are around 148-174 MHz in the VHF band, and typically 414-430 and 450-480 MHz in the UHF band. Line of sight between transmitter and receiver is required at these frequencies. Licences for data in urban areas where many of the available VHF channels are already assigned for voice communications are generally allocated to the UHF band. VHF is preferred for mine installations because it has slightly better range than UHF.

Communications Canada policy is to treat radio frequencies as a national resource. Accordingly, they want to maximize their use and could conceivably refuse a licence for a data radio system if they think the use is not critical, or that the end result could be achieved in other ways. Currently, this policy probably wouldn't affect mines that are 100 miles or more from cities, since there is little competition for licences in unpopulated areas. However, this policy could change in the very near future.

3.5 Bandwidth

In the USA, licences are tending to be allocated above 800 MHz with narrower bandwidth limits. This may result in the development of MSK schemes in favour of FSK schemes. Bandwidths required for data radio communications systems do not currently present any major problems in Canada under 500 MHz, and are unlikely to in remote mining areas.

3.6 Performance Criteria

Six key areas are of interest in evaluating a mobile data system: channel throughput, error control, access time, vehicles per channel, undetected error rate and radio RF power.

3.6.1 Channel Throughput

Channel throughput refers to the number of correct messages that the system can handle per unit of time, typically one hour. This of course is a function of the size of the message in a particular application, for example, a dispatch message for a truck to go to a particular shovel.

Throughput is a function of several other factors, including raw data bit rate, protocol efficiency, the number of transmission retries necessary when errors are detected due to multipath interference, electrical interference and other factors, and the turn-around time of the radio hardware.

The message to be transmitted is almost always accompanied by what is called redundant information or overhead. For example, a data string using a Synchronous Data Link Control (SDLC) protocol uses the following frame format:

flag	8 bits
address	8 bits
address	8 bits
MESSAGE	variable
frame check sequence	16 bits
flag	8 bits
Total	48 bits PLUS MESSAGE

If the message is ten characters of 7 bits each, the message length is 70 bits, resulting in a protocol efficiency of:

$$\frac{70}{48 + 70} = 59\%$$

When the data string is received, it is acknowledged by the receiving end. This requires that the receiving end power up its transmitter and send information. This turnaround time can be relatively lengthy if the radio equipment used is not designed for data communications use. For short messages, the turnaround time of the equipment can exceed the time required to send the data.

For applications where the message is relatively short, the overhead can equal or exceed the message in total time required to transmit.

Data rates for mobile communications range from less than 100 to over 4800 bits per second (bps). This factor in itself is meaningless in assessing the overall channel throughput. Systems with very low raw bit rates can have greater channel throughputs than 4800 bps systems depending

on the radio protocols used, and technical characteristics of the radio system. The only true measure of performance is the channel throughput.

Before the originating station can receive a confirmation after turning off its transmitter, it must switch on its receiver. The time required for the receiver to be in full ready mode is called the receiver attack time. It can vary from about 15 ms for data radios to as high as 250-400 ms for typical voice radios used for data.

The receiver attack time is extremely critical in volunteer systems to know when the channel is clear. If the attack time window is large, it significantly increases the probability of two systems trying to transmit at once.

The sequence of events in a volunteer system might be as follows. All the remote stations are in the receive mode, listening to see if the channel is occupied. When one station has information to transmit, it will withhold its transmission until the channel is clear. This is called a "carrier detect" system.

1. Remote station has information to send	
2. Channel is clear, so it powers up its transmitter	
Transmitter power up time	20 - 500 ms
3. Message is sent	
Data transmission time 118 bits @ 1200 bps	10 ms
4. Processing by receiving station say	5 ms
5. Acknowledgement	
Base station power-up	20 - 500 ms
6. Base station data	variable
TOTAL	55 - 1015 ms + base data

In general, about 50% of message is redundant overall, plus there is time required for the acknowledgement.

3.6.2 Error Control

Errors in the data will occur because of multipath interference and external electrical noise pulses. Multi-path interference occurs because the receiving station receives both a direct signal and one that is reflected off a pit wall or building. This reflected signal arrives slightly later and out of phase with the direct signal. This can cause reinforcement or cancellation (fading) of the received signal

There is considerable impulse noise in mines caused by switching of high currents at shovels and on diesel/electric trucks. Noise bursts can last typically from 1 to 10 milliseconds (mS). For a 1200 bps system, each bit takes just under one mS, so a longer noise pulse would wipe out over 10 bits of information in the transmission.

Errors are detected, and with some protocols, corrected, by adding redundant information to the transmission. Using error detection alone requires that the message be repeated if an error occurs. Simple parity checking schemes are not suitable for radio. Since multiple bits can be lost, errors could go undetected. While this may not be critical in certain applications, it could result in considerable inconvenience and confusion.

Forward error correction (FEC) can be used to reconstruct messages that have errors. FEC schemes however add a lot of overhead to the transmission. There is a tradeoff to be considered between types of FEC. A powerful error correction code will result in fewer re-transmissions but requires many redundant error correcting bits that reduce protocol efficiency and throughput. A weaker but shorter code may require more re-transmissions.

In certain applications it is perfectly valid for the receiving station to transmit the entire received message back to the sender for 100% verification. In other situations, the sending station is automatic and there isn't a way for the sender to correct defective information so the sender may simply send the same message twice. This type of scheme could be used for marker beacon identification of trucks, since it would not be possible for the driver to turn around and drive by the beacon again, and the base station software could infer his position if necessary.

FEC for every message results in a lot of overhead: generally 40 to 60% of the message for radio..

For some data schemes, FEC isn't really required. For example, HSC requires no FEC because to corrupt a bit is almost impossible. The price paid for this immunity is speed. In HSC, one tone representing one character lasts 33 mS.

3.6.3 Channel Control

The rules of access to the radio channel are governed by the channel control scheme used. There are two broad techniques used: polling and volunteer. In a polled scheme, the base station interrogates each remote station in turn and asks it if it has any information to transmit. If it has, it sends the information. Polling schemes are generally inefficient for short message applications because of the total time consumed by transmitter switching times and other delays. In many applications, there will be cases where a considerable portion of air time for polling will be wasted because there is no new information to be sent by the remote station. Polling for a truck dispatch system would be inefficient because truck status can remain unchanged for periods of several minutes. If a polling cycle is say 4 seconds, a truck whose status remains unchanged for say 5 minutes will be polled unnecessarily 75 times. Polling schemes are generally not used in most modern mobile data radio schemes.

Polling schemes could have an application where large blocks of data have to be downloaded from remote terminals, and where this information is not needed real-time. For example, a polling scheme could be used to download health monitoring information stored on a vehicle a few times per shift while there is little activity on the radio channel for say dispatching.

Volunteer control schemes are preferred where the data is needed real time. In volunteer schemes, the data transfer is initiated by the remote terminal. There are two ways to accomplish this. One is to have no control at all, whereby any station that has information to send transmits it without regard to the fact that another unit may already be occupying the channel. This scheme developed by the University of Hawaii is called the Aloha protocol. If a data collision occurs, the sending stations do not receive an acknowledgement from the base station and they will retry their message after a randomly-generated waiting period. This scheme degrades rapidly when use increases.

The preferred schemes use carrier sense, whereby a station that has a message will first listen in on the radio channel to see if it's busy, and will transmit only when it's free. There is still a small chance that a collision will occur during the period when the station is going through its

brief transmitter warm-up. If another station wants to transmit at this time, it will not yet detect the other and a collision will occur. When this happens, the stations will have to back off a random period of time before trying again just as in the Aloha scheme.

3.6.4 Access Time

Access time is the time required from the time the send or transmit key is pressed to the time the message is successfully received and acknowledged. Access times as high as five seconds are found in certain mobile data systems. A reasonable specification for a mine data system is an access time of less than one second. Two factors significantly affect access time: data rate and the number of re-transmissions.

3.6.5 Radio Frequency Power Output

A higher radio frequency (RF) power output can help overcome errors and the need for re-transmissions caused by fading. Less power is required for a point to point fixed radio system than mobile systems which are operating in an ever changing reflection environment. Significantly less power is required in modulation/protocol schemes that are more immune to multipath and noise interference. In better data radio systems, data messages can be transmitted without error in voice radio 'blind spots' where speech transmissions cannot be understood.

The maximum power output is controlled by Communications Canada.

3.6.6 Vehicles Per Channel

The number of vehicles per channel that a system can handle can be determined only by the particular mine configuration, the nature of the data to be sent, the protocol used, and the specifications of the radio transceiver.

4. AVAILABLE TECHNOLOGY

4.1 Introduction

This review of specific data radio communications is intended to serve two purposes:

i) To provide an overview of some of the different approaches that can be taken for different applications.

ii) To examine systems that either are used or are proposed for use in a mining environment.

There are hundreds of data radio communications systems in use, most of them designed for very specific needs. Some of these include end-of-train monitors, packet switching systems via terrestrial microwave, taxi dispatching systems, very small aperture terminal (VSAT) satellite systems for providing sales and inventory information from distant retail outlets to company headquarters, pipeline monitoring and control, and many more. A detailed review of all types of data communications systems is beyond the scope of this report. The systems discussed were chosen because they have the greatest potential applicability.

In reviewing the technology, it is critical to understand that mobile data radio communications systems are not "off-the-shelf" products. Systems are designed using particular combinations of specialized software for the application, computer hardware, radio hardware, terminal hardware and software, and data transfer protocols. Accordingly, it is generally not possible to go to a manufacturer of radio communications equipment and expect to receive a system that will answer all of one's needs.

The nature of the data, whether messages are very long or very short, the need for the information in real time, and the expected traffic volume will all influence the choice of the most appropriate system for a particular application.

4.2 Advanced Electronic Systems Ltd.

AESL produces a comprehensive vehicle monitoring system which collects pressures, temperatures, fluid levels, and analog information on-board the machine. This information is processed and stored on-board. Data transfer to a base computer is accomplished with a data radio system. The data sent to the base computer can be further analysed and used for reporting.

The AESL literature presents two data radio options. They recommend frequency of 420 MHz because it is the currently favoured band by the DOC and is reported to be relatively quiet and noise free.

The first radio option suggested is the use of an un-modified voice-grade radio operating at 2400 bps. The second is a custom unit operating at 8000 bps. The data protocol is similar to IBM SDLC. The data packets consist of the destination address, source address, a control byte, data bytes and a 16 bit CRC enclosed between two flag bytes

The radio system operates in the simplex mode. It relies on the base computer to initiate by polling. If the transmission from the vehicle is error free, then the base computer reads the contents, otherwise a control byte is sent to the vehicle requesting re-transmission. Such requests are sent three times before the vehicle is deemed to be not communicating and the base polls the next vehicle.

Another system referred to in AESL's literature is called the Smart Antenna. It is proposed for underground data communications to collect data from moving vehicles as they pass radio nodes distributed along a hardwired system. This could have some applicability for open pit mines if the radio nodes are linked with radios instead of wires.

The system is described as follows. The hardwired portion is two twisted pairs: one for DC to power the radios, the other for data in RS-485/422 format at approximately 200 Kilo baud. The radio nodes are placed at strategically important locations, for example at drawpoints. Network line repeaters are located along data highway.

The radios on the nodes which communicate with the passing vehicles are low power, about 50 mw, which will cover about a 100 foot radius. The vehicle-node FM radio system operates at 450 MHz at data rates of 8000 bps.

Local intelligence and memory are provided at each node to detect a transmission from a passing vehicle, provide a data handshake, and read and store the information dumped from the vehicle. The node also monitors the network and base computer poll requests, then passes the stored data to the network cable. Error detection is provided for communications with the base computer and mobiles.

A communications controller terminates the network cable at the fleet base computer. It handles protocol and handshaking and has a buffer, and has the power supply to feed the network radio nodes and repeaters.

The data format is similar to SDLC packet. The SDLC format has a fixed overhead of 48 bits for each information frame for flags, control, addressing and error detection. If the data to be sent is only a few bits, then the amount of overhead is relatively high. Accordingly, this format does not lend itself as well to very short duration messages such as for dispatching systems.

The communications system used with AESL's applications appears to fit well with its application, but would not appear suitable for short message applications such as dispatching and real time production monitoring.

4.3 ASW Computer Systems Ltd.

ASW is currently working on a project with CANMET to design, develop and test a data radio system. ASW anticipates that the system will be used in on-going open pit mine research activities for CANMET, and be used on mining equipment and for geotechnical monitors.

They anticipate that later development might see the system used for such functions as truck location systems, truck dispatch systems and applications to monitor remote field instruments.

The system envisaged by ASW will consist of a network of nodes located in the field, with each node responsible for only one device. Each node will have a single board computer, power supply, radio, and modem, and will be suitable packaged.

The interface between the node and the device is a standardized protocol with selectable baud rate interconnected with an RS-232 cable. The node accepts raw telemetry data, packages it, and transmits the data through an RF channel to the base, either directly or through another node in the network. The system provides for message routing through intermediate nodes which are used as message repeaters. The goal is to provide end-to-end message transfer in under one second, and a maximum error rate of 1%.

The system proposes to use a carrier-sense multiple access scheme for channel control. To minimize collisions, the node monitors the radio channel. If it detects a carrier, it withholds its transmission attempt for a predetermined time.

To preserve power at the nodes, each node will remain in a 'sleep' mode with only its receiver turned on. When a carrier is detected, the radio and microprocessor are awakened, and the address is decoded. If the address in the message corresponds to that node, it carries out the

instruction, whether to act as a repeater to another node, or to perform some other function. It goes back to sleep if the address does not correspond.

The recommended power for each node radio is 25 watts, operating in a simplex mode at a frequency of 170 MHz. ASW proposed to use Motorola Maxar 80 radios. These units, however, are no longer made, so another unit will have to be substituted. The Maxar 80's are a voice radio and accordingly have receiver attack and transmitter warm-up times that are very long and generally unsuitable for short-message, high volume data traffic. This type of radio may prove to be quite satisfactory however for certain monitoring applications.

The modem proposed will use a Bell 202 standard FSK scheme. It will have a default configuration of 1200 baud, even parity, 1 stop bit, and 8 data bits.

Parity validation and cyclic redundancy check (CRC) are proposed for error detection. If an error is detected, the receiving station sends a negative acknowledgement message and the source re-transmits the signal. Forward error correction is not proposed because it introduces too much overhead.

Another error detection and correction scheme discussed is multiple message transmission, where the originating station repeats the package several times. At least two contiguous packets must be received to be accepted. This is not proposed for now, but may be reconsidered if the lengths of most messages are short.

The information transmitted will be limited to 256 bytes or less. If there are more than 256 bytes in the message, it will be broken up into separate packets.

For data transfer systems with short messages such as real time production monitoring, dispatching, and vital signs monitoring, the ASW system contains a lot of overhead, both in the protocol and in the switching times introduced by the hardware. The routing information alone contains 6 bytes of overhead (1 byte for the destination node and 5 bytes for the relay node). Having the units in a sleep mode, while adding to battery life, requires longer pre-transmit times, and can be subject to falsing.

This system will probably be most suitable for low volume non-real time applications, such as monitoring field devices. The suggested scheme does not address how the routing scheme could be used for moving trucks.

4.4 Mobile Data International (MDI)

MDI has been highly successful in the mobile data communications business, with their major markets being taxi and utility vehicle dispatch systems, public safety vehicle data enquiry and reporting, and dispatch and tracking of couriers and their packages.

The systems operate at a 4800 bps, and have a sophisticated forward error correction scheme. Their terminal types vary by application: CRT terminals are used in public safety and some courier vehicles, simpler LCD readout terminals for taxis, and portable hand-held terminals with keyboards and LCD readouts for a variety of applications.

MDI has used a number of different radio manufacturers for their data systems depending on the application, but they may now use primarily Motorola since Motorola has purchased the company.

Their data communications systems could be adapted to the needs of the mining industry, although the company has had no experience at mines. The hardware costs could be over twice the cost of the system currently produced by another supplier, and engineering support for the first installations could run up to $200,000 per site.

The MDI equipment is highly regarded, however, their involvement is not suggested at this time because: 1) the cost of their equipment and services is significantly higher than an existing product already used in the mining industry, 2) the company has no experience in mining, and 3) their products do not expand the capability already existing in the industry.

4.5 Mobiltex Data Ltd.

Among the products manufactured by the company are mobile industrial data terminals, mobile radio accessory products, hexadecimal sequential code radio modems, industrial radio paging systems, and two-way radio voice scramblers.

Mobiltex currently manufactures the mobile data terminals for the Wenco International Production Monitor and Control System (PMCS). They are designed to operate either with an internal data radio or can be interfaced to existing voice radios. The system described below uses the internal data radio.

The system is a 'volunteer' system with carrier sense and collision detection. It is not a polling system. When a mobile unit has information to send, it automatically

transmits it to the base modem if it senses that the channel is clear.

The data radio system was specifically designed for the mine environment. It is based on a variation of the signalling scheme recently developed for pocket paging systems. This system, called hexadecimal sequential coding (HSC), is a multi-tone system consisting of one of several tone frequencies in bursts of 33 mS, each representing a character. The proprietary protocol used is a subset of HSC developed specially for this mining application.

HSC is well suited for the mining environment because the timing relationships in the protocol makes it virtually immune to burst noise and multipath interference. The HSC format provides a 99.9% decode probability at 0 dB signal to noise ratio. The 33 mS HSC tone burst lasts well over the 1-10 mS time for a typical noise impulse.

The relevant specification of the radio transceiver are:

Receiver attack time:

The data radios have an attack time of 15 mS worst case, with 5 to 6 mS being typical. The value for typical voice radios is 250-400 mS. Receiver attack time is extremely critical in volunteer systems to know when the channel is clear. If the attack time window is large, it significantly increases the probability of two systems trying to transmit at once.

Transmitter power up time:

The radios are capable of a 25 mS warm-up time. If a repeater is used, the warm-up time is set up for 50-60 mS because of the time required at the repeater. Conventional voice radios require 300-500 mS with relay switching and 150- 500 mS without relay switching.

If more than one truck tries to transmit within the 15 mS receiver attack time window, a collision will occur and the trucks will not receive the proper acknowledgement from the base modem. They are programmed to retry again after a randomly generated delay period. Once the signal is received by the base modem, it re-transmits the signal back to the truck for full verification. If the message is valid, no further action is taken. If the messages do not match, the truck radio will automatically retry its transmission up to three more times.

The characteristics of HSC are such that forward error correction and detection are not required. HSC with no error correction provides several times more range than FSK with forward error correction.

Mobiltex have chosen to structure their protocol such that there is 100% verification. Upon completion of the transmission from the originating unit, the receiving unit transmits it back for verification. If it is not identical to the original, a re-transmission is required. In operation, first try errors requiring re-transmission occur less than one percent of the time.

Total message time, including 100% verification, is 820 mS for operator interactive systems. This is broken down as follows:

- mobile transmitter and repeater power-up:	60mS
- data transmission (10 digits @ 33mS)	330mS
- base modem turn-around time including processing and modem transmitter power-up	70mS
- re-transmission of the data back to the mobile:	330mS
- end of transmission quiet time	30mS
TOTAL	820mS

The number of vehicles that can be handled per channel is highly dependent on haul distances, vehicle speed, system protocol and data radio turnaround time. For a 22 truck mine with 40 loads per hour of ore and 20 loads per hour of waste, the radio channel would be occupied approximately 6.9% of the time. Above 50% air time, minor radio response time delays may occur during peak times such as reassignments at shift change and after coffee and lunch breaks. Based on this example, over 150 trucks could be accommodated on a single channel.

This is based on the following assumptions:

40 loads/hour of ore
5 radio messages per truck per ore load cycle
20 loads/hour of waste
5 radio messages per truck per waste load cycle
820mS per radio message
22 trucks operating

$$\text{Radio air time} = \frac{[(40 \times 5) + (20 \times 5)]\ 0.82}{60 \times 60} = 6.8\%$$

Allowing for transmission retries at a rate of one per every 100 messages, air time would be 6.9%.

This assumes that each ore truck cycle will result in four status information transmissions: one from the shovel (FINISH LOAD) AND three from the truck (DUMP; ARRIVE AT SHOVEL; START LOAD). In addition, one transmission per

cycle is required for the dispatch instruction. A total of five transmissions will then be required for one haul cycle.

Because the system can operate under very poor S/N conditions (99.9% decode probability at 0 dB S/N), it has excellent range. The 5 watt output power has been ample in mines which are located in mountainous areas and quite spread out. Experience with the system has shown that it can operate anywhere that a 30 watt voice radio will operate.

5. DISCUSSION AND RECOMMENDATIONS

5.1 Merits of Integration on a Single Channel

In principle, it appears sensible to combine various sources of data into a common data radio channel. Arguments in favour of this are:

i) Radio channel use is maximized. It is desirable to treat frequency allocations as a scarce resource, so optimizing the use of each frequency is desirable. However, the majority of mines are in remote areas where there is not and likely will never be a high demand for frequency allocations.

ii) Minimized duplication of radio hardware and associated maintenance. Including the voice radio system, some trucks could conceivable have up to four or five radio systems serving individual applications.

There are, however, some compelling arguments against combining data from various systems. These are:

i) Supplier responsibility. The systems to be served by an integrated data transfer system are generally made by different manufacturers. The integrated data system would in effect be a common carrier like a telephone company. The danger is that there is no one to regulate the "carrier", and many systems suppliers would be very reluctant to rely on another for the vital task of information transfer.

ii) Channel crowding. Dispatching systems generate a lot of data traffic. A coal mine in Northeast British Columbia required three radio channels for the dispatching task alone. Accordingly, adding more data irrelevant to the main task of the system would accomplish little. Smaller systems, of say up to 30 trucks, do have some spare radio time which could be made available for other data.

iii) Data priority and message length. As discussed earlier, the nature and length of messages are different depending on the need:

Real-time/short messages	Non Real-time/long messages
* production monitoring	* vehicle health monitoring
* dispatching	* geotechnical monitoring
* equipment location	
* vital signs monitoring	

The protocols used for short and long messages are generally different. A long message protocol may use sophisticated error correction to minimize the need for re-transmissions. To a short message, this would add unacceptably to the overhead. Accordingly, mixing two message types in one protocol may result in unsatisfactory compromises.

iv) Information Destination. Vehicle health monitoring information is needed by the maintenance group in the mine, whereas the production personnel are concerned with production monitoring, vehicle location and dispatching information. These two groups have different priorities and are often even located in different areas of the mine. Unless an inter-computer communications network is set up, the distribution of the information to the various groups presents problems. These problems can be solved technically, but practical experience suggests that it would not be easy.

5.2 Alternatives

Three alternatives can be considered:

A. Do Nothing.

Defer development of an integrated data transfer system until the mines have a clearer understanding of their own needs, and until further developments have taken place in the individual systems being considered for integration.

B. Integrate by Type and Destination of the Data.

This would result in integrating all the real-time applications for use by the production group into one system, and the integration of non-real-time applications such as vehicle health monitoring and geotechnical instrument monitoring into another system.

C. Develop a Universal Data Transfer System.

The development of a universal data transfer system is possible but would require a considerable amount of research and development.

5.3 Recommended Development

We recommend a variation of Option B:

i) Integrate the real time/short message applications

ii) Defer the integration of the non-real-time, long message applications until further study has been done and the applications have developed to the point where there are more field installations.

Data for truck dispatching and associated location monitoring can effectively be combined with vital signs monitoring. Information that is not needed real time such as vehicle health monitoring data, and data from field monitors such as geotechnical data should be restricted to separate channels.

The reasons for these recommendations are:

1. It is not clear that there would be a net cost saving to a system purchaser to combine all data through one radio channel. While there may be a hardware saving initially, this may be offset by the additional software required, extra costs charged by vendors to coordinate the system operation, and indirect costs to the customer when one or more system fails and responsibility for repair is unclear or disputed.

2. Unlike crowded urban areas where radio channels are at a premium, open pit mines are invariably located in remote areas where Communications Canada is more likely to grant extra radio channels for different applications.

3. Radio channels for dispatching and other real-time requirements may be approaching capacity, so adding higher volume information like vehicle health could result in the need for an additional channel anyway.

4. Equipment vendors may be reluctant to rely on another vendors data radio highway to transmit their data. If a mine decides to replace or discontinue the use of the system containing the data radio system, it would spell disaster for the other system. While a certain amount of integration is required, separating the data by time urgency may partially meet supplier concerns.

5. Radio systems currently being used for truck dispatching operate very satisfactorily and would appear able to meet anticipated needs for future dispatching and also be able to incorporate vital signs monitoring.

We recommend that the integration of the real-time system be undertaken by Mobiltex Data Ltd. because they already make a successful system in use in the mining industry. It is well suited to short messages, and the information to be integrated can be readily incorporated into the Wenco International PMCS system.

Although vital signs monitoring is technically a concern of the maintenance group, the information can be collected and reported through the production group if the mine has no other facility for transmitting this information.

The integration of the non-real-time information should be reviewed along as part of the recommended work for equipment monitoring in Phase 2.

APPENDIX VII

LOCATION MONITORING, DETAILED ANALYSIS

VEHICLE LOCATION AND DISPLAY SYSTEM

FOR AN

OPEN PIT MINING OPERATION

Submitted to:

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July 15, 1988

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APPENDIX I REFERENCES

1. INTRODUCTION

Pulsearch in conjunction with Krakiwsky Consultants Ltd. and the Surveying Department of the University of Calgary will develop the hardware and program software that will locate and continuously update equipment location using both a radio navigation and GPS system for application in an operating open pit mine. The overall intent of the program will be to use existing technology to confirm proof of concept.

The proposed vehicle location system is an assembly of technologies and equipment that permits centralized and automatic determination and display of the position and movement of the vehicles throughout the mine area. The result of this system will be integrated into the WENCO integrated mine program that drives the dispatching module.

The primary positioning system will be terrestrial radio navigation or the G.P.S. systems. Real time positions are transmitted to the control centre which indicates the position on a map of the mine. The transmission of the position data will be left to Wenco and it may be done automatically by the computer on board.

The first phase of the project will be utilized to develop and test the hardware and software components. The second phase will include the integration and field implementation of the system in an operating mine for an evaluation period to be determined. The second phase will include the system evaluation, report, and recommendation for final system development and commercialization.

2. EXISTING AND DEVELOPING AVL SYSTEMS

The authors have researched the literature and found that a total of at least 22 AVL systems exist and are under continuous development and improvement (Tables 2-1 and 2-2). Fifteen are stand alone autonomous systems, while seven are centralized dispatch type systems. This is ample evidence for the belief that the 1990's will be a period in which AVL systems will blossom. They will be highly specialized and hence aimed at a certain spectrum of the market. No one system will be capable of serving the entire market, hence the proposed AVL - mining system (see Chapter 3).

The one component of AVL systems that is more or less a common denominator for on-road applications is the digital-computer map. Nevertheless, even this component will need extensive customizing especially for off-road applications like in open pit mining. This customizing will depend upon the special feature(s) of the particular AVL system. To illustrate this point, witness the AVL 2000 system (Tables 2-1 and 2-2). Two levels of customizing had to be done: the first, occurred in developing the map database itself from a transportation network database, and a second level occurred in establishing the route database so that minimum route calculation could be done in real time in the vehicle.

So called public-based AVL systems are illustrated by the Autogarde System. Note, the characteristics and components of this system are quite different from, say, the Buick Questor System which is essentially a self-contained non dispatch AVL system.

After studying the various attributes of AVL systems it is clear that there is no adequate dispatch oriented AVL system to report positions of fleets of vehicles. The car manufacturers are concentrating on self-contained autonomous AVL systems for private cars.

The above makes the case for a customized approach that would address the specific needs of an open pit mining operation and such a system has already been studied and conceptualized (see AVL 2000 - Mining Systems in Table 2-2).

AVL SYSTEMS	HARDWARE							SOFTWARE				
	NAVIGATION SYSTEM	COMPUTER		INPUT FACILITIES	OUTPUT FACILITIES		ELECTRONIC MAP STORAGE	ZOOMING ALGORITHM	SPEECH ALGORITHM	OPTIMIZED ROUTE ALGOR.	POSITION / TRACK ALGORITHM	DATABASE / DISP. MANIP. ALGORITHM
		MICRO-PROCESSOR	MICRO-COMPUTER		CRT DISPLAY SCREEN	VOICE OUTPUT						
ETAK NAVIGATOR	closed loop dead reckoning	8088 chip	no	keypad	vector display	no	digitally encod-ed map cass.	yes	no	no	yes	yes
CARGUIDE	n/i	68000 chip	no	keyboard	video display	yes	bubble memory	yes	yes	divide and conquer	n/i	yes
VDO CITYPILOT	dead reckoning	yes	no	keyboard or light pen	yes	no	special map sheets	no	no	no	yes	no
MICROPILOT	dead reckoning		Apple II	keyboard and voice input	no	yes	storage in comp. mem.	no	yes	yes	yes	yes
AVL 2000 (Prototype)	GPS satellite positioning		Mac Plus	keyboard	vector display	no	hard disk MacPlus	yes	no	patch quilt concept	GPS point position	relat-ional D.B.
AVL 2000 (First Gen.)[1]	GPS and dead reckoning	68000 chip	no	keyboard and voice input	vector display	yes	CD-ROM	yes	yes	patch quilt concept	GPS point position	relat-ional D.B.
CHRYSLER : CLASS	GPS positioning		yes	finger touch control	colour video display	no	video disks	no	no	no	GPS point position	yes
NISSAN : CUE - X	satellite positioning		yes	keyboard	yes	no	n/i	no	no	no	yes	yes
ELECTRO GYRO-CATOR[2]	dead reckoning		yes	no	yes	no	photographic map storage	no	no	no	dead reck-oning	no
BUICK : QUESTOR[3]	no		yes	keyboard	colour graphics	no	digitally encod-ed tape cass.	no	no	no	yes	yes
FORD TRIPMONITOR	dead reckoning & sat.system		yes	finger touch control	colour graphics	no	n/i	no	no	no	yes	yes
PHILIPS CARIN	dead reckoning	yes	no	keyboard	yes	yes	CD-ROM	no	yes	yes	yes	yes
BOSCH / BLAUPUNKT	dead reckoning		yes	keypad	simplif. graphics	yes	EPROM and CD-ROM	no	yes	yes	yes	yes
DAIMLER - BENZ	n/i	2 - 6801 chips	yes	keyboard	yes	no	n/i	no	no	yes	n/i	yes
NAVIGATOR	uses database to coordinate road network	2 - 6801 chips	no	keyboard	yes	yes	bubble memory	no	yes	yes	no	yes

1 expert system concept implemented
2 maps are overlaid onto display screen
3 navigation program on cassettes

TABLE 2-1 STAND ALONE SYSTEMS

AVL SYSTEMS	HARDWARE										SOFTWARE			
	NAVIGATION SYSTEM	COMPUTER		INPUT FACILITIES			OUTPUT FACILITIES			MAP STORAGE	OPTIMAL ROUTE ALGORITHM	AUXILARY ROUTE ALGORITHM	POSITION / TRACK ALGORITHM	DATABASE / DISP. MANIP. ALGORITHM
		BASE UNIT	MOBILE UNIT	BASE UNIT	MOBILE UNIT	ROADSIDE UNIT	BASE UNIT	MOBILE UNIT	ROADSIDE UNIT					
FLAIR	dead reckoning	central processor	vehicle data proc.	CP tracking table	coded keypad		video disp.; radio trans.	trans./ receiv.		map database stored in central proc.	no	yes	yes	yes with zoom capab.
MAGNAVOX	dead reckoning and TRANSIT satellite syst.	IBM PC-AT	MX - 6102 terrain nav	keyboard, VHF-FM trans./rec.	same as base unit		colour graph.; trans./ receiv.	trans./ receiv.		n/l	no	no	yes	yes
MOTOROLA	navigation done by driver	Motorola KDT data terminal	n/l	trans./ receiv.	trans./ receiv.		trans./ receiv.	trans./ receiv.		no	no	no	no	no
II MORROW	navigation done by driver	Motorola KDT data terminal	n/l	trans./ receiv.	trans./ receiv.		CRT & trans./ receiv.	CRT & trans./ receiv.		map storage in data terminal	no	no	no	yes
AVL 2000 mining	TRANSIT satellite system	mini-computer	micro processor		keyboard & lightpen	audio & digital message		CRT & voice	CRT & voice	database stored in central proc.	yes	yes	yes	yes
INDUCTIVE LOOP BASED GUIDANCE SYSTEM	proximity syst. (inductive loop buried in road)	n/l	n/l		key board	trans./ receiv. induct. loop		CRT display	induct. loop	map database stored in roadside unit	yes	no	no	yes
AUTOGUIDE	proximity syst. (electronic signposts)	central processor	route terminal		keyboard trans./ receiv.	radio beacon		CRT dispay & voice	radio beacon	map database stored in roadside unit	yes	no	no	yes

TABLE 2-2 DISPATCH (CENTRALIZED) AVL SYSTEMS

3. PROPOSED SYSTEM

3.1 Overview of a Vehicle Location Mining System

A vehicle location mining system is comprised of many mobile units and a single dispatch unit (Figure 3-1). Each mobile unit receives sensor input, processes some data, and prepares output for transmission. The mobile units are equipped with a communication unit for sending and receiving information to and from the dispatch unit. The dispatch unit also receives input, processes data and prepares some output for transmission.

Figure 3-2 depicts a mining system designed for an open pit mining application. Two sources of input for each mobile unit are as follows:

(a) the driver's status report which is entered by means of a keypad (Wenco's Status System).

(b) the unit's real-time positions result from the combination of one or more positioning sensors.

The latter input is directly to the microprocessor, while the status report is made directly to the communication unit in readiness for transmission to the dispatch unit.

The operations performed in each mobile unit include initialization of a days operation, sensor and system calibration and computation of real-time positions, and sending and receiving information to and from the dispatch centre.

The dispatch unit is responsible for overall management, allocation, and dispatching. The only manual input to this unit is the operator's interaction by means of: (a) a keyboard; and (b) a mouse or a light pen.

The operations performed in a dispatch unit include initialization at the beginning of each day's operation, dispatch allocation, and communication with mobile units.

FIGURE 3-1. AVL MINING SYSTEM OVERVIEW

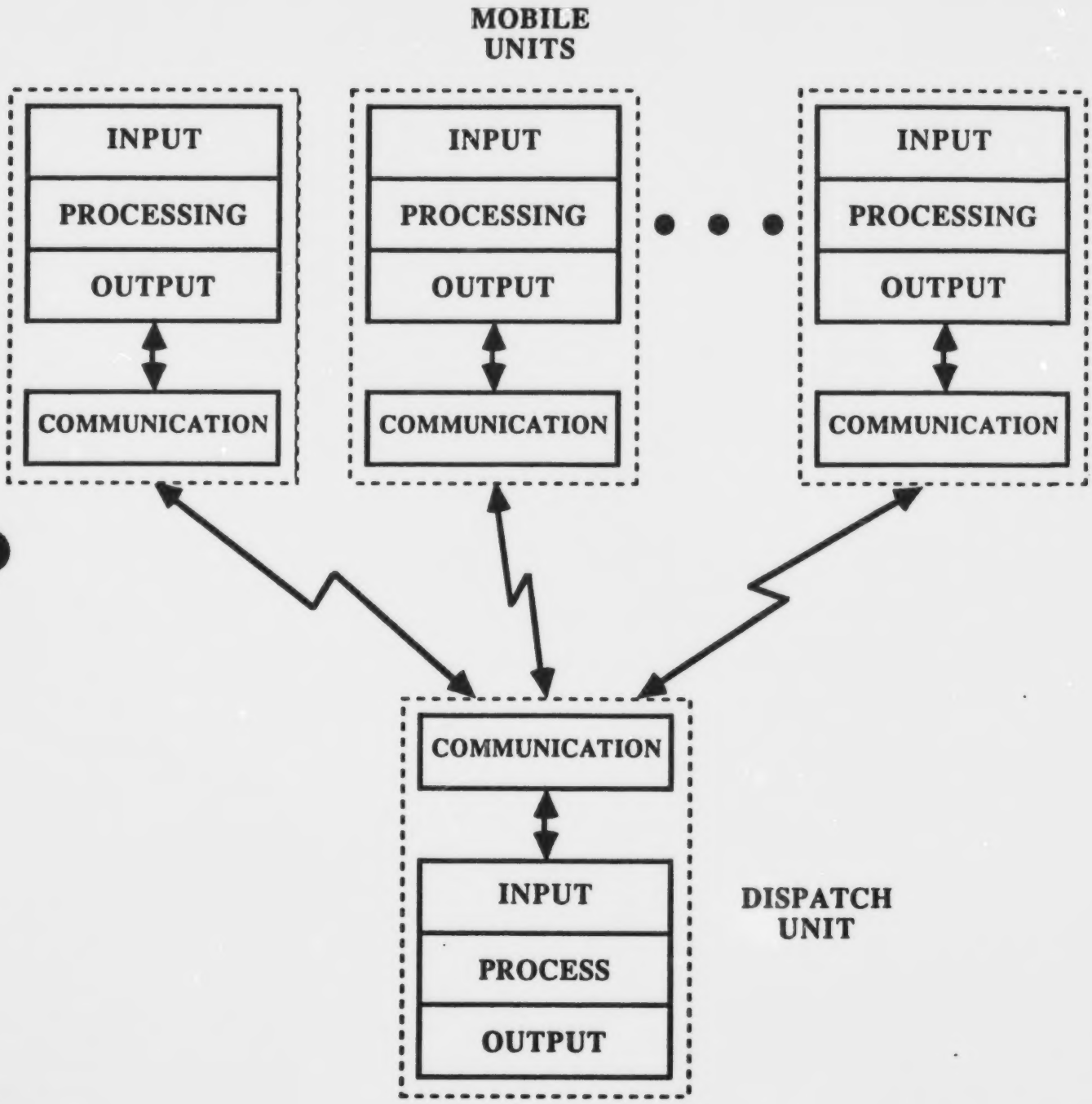
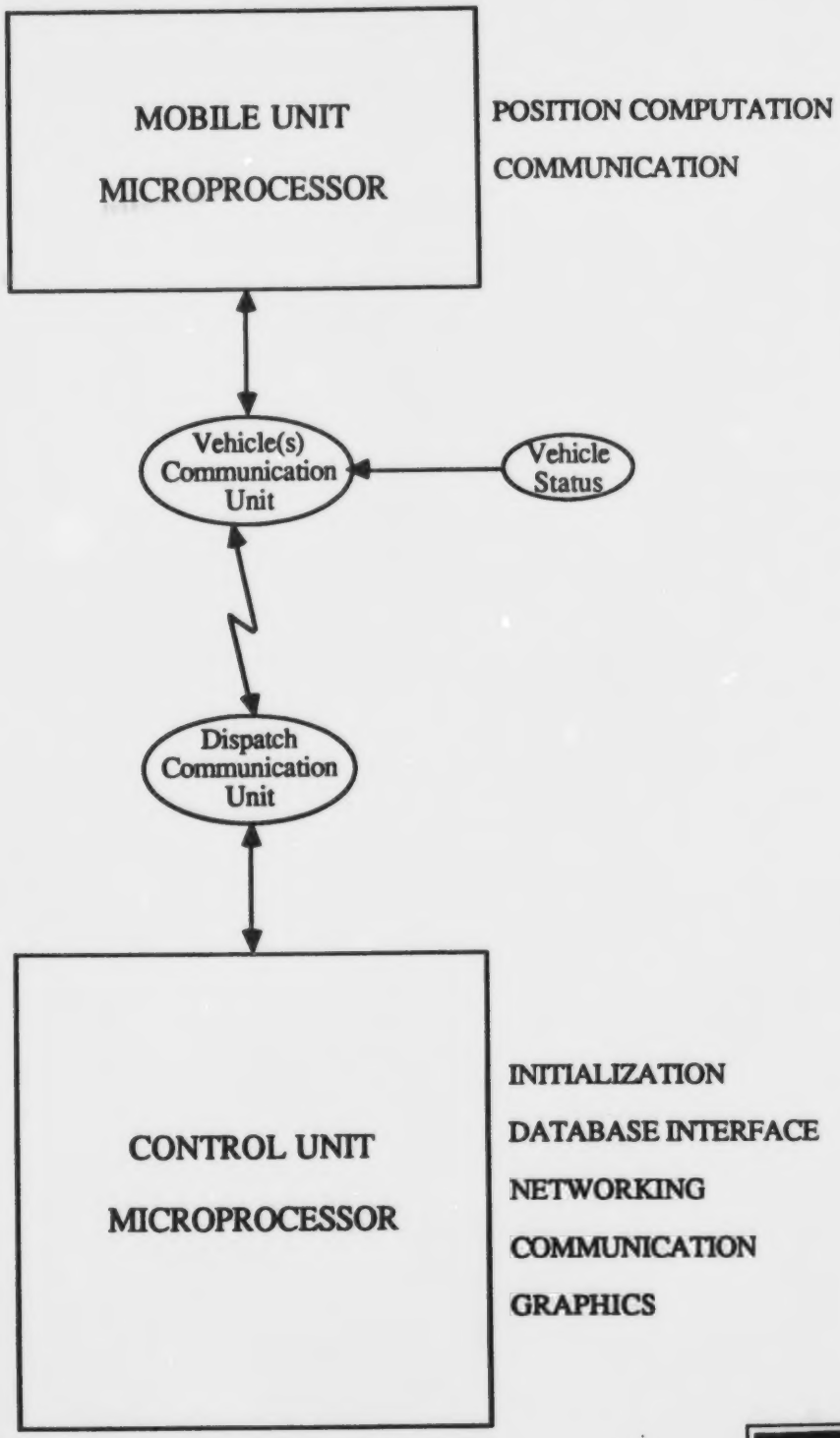


FIGURE 3-2. AVL MINING SYSTEM



3.2 Processor Hardware Components

The only output device necessary in a dispatch unit is a Cathode Ray Tube (CRT) display for viewing the Digital Terrain Model (DTM) map of the entire mining operation with all the mobile units real-time positions superimposed, and shovel and vehicle allocation information.

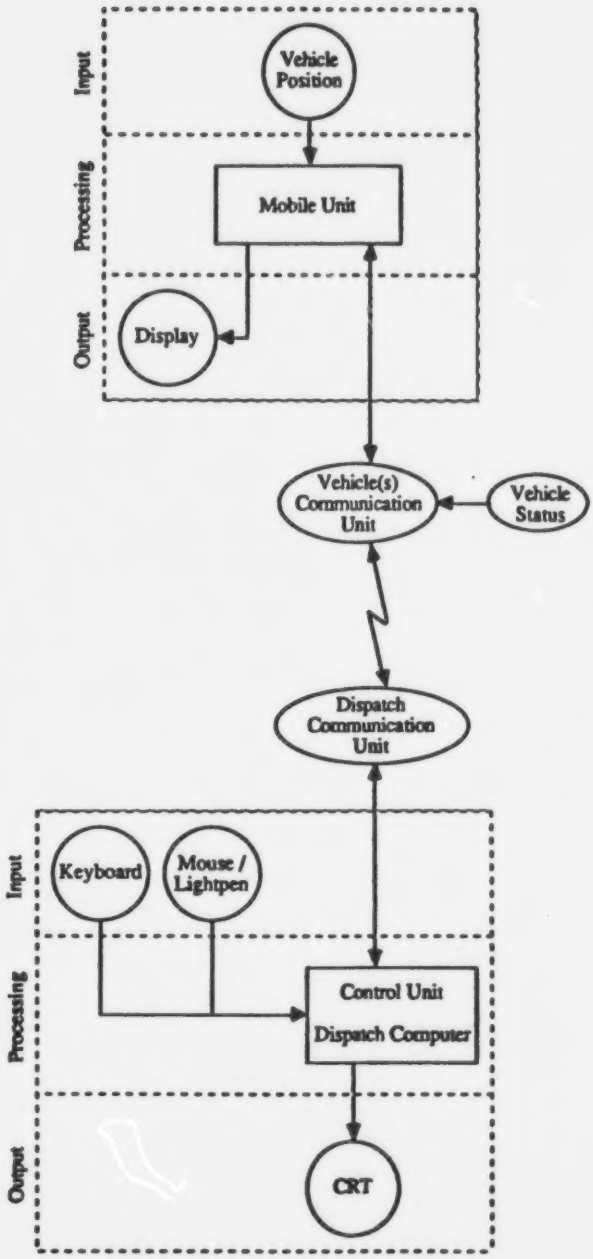
The hardware components of the designed mining system are shown in Figure 3-3.

The mobile unit processor must be as compact as possible. This dictates the employment of a microprocessor, either in a custom designed form or in a microcomputer form. For simplicity, however, a (small) microcomputer with appropriate speed and capacity is proposed here. In this case, the criteria for the choice of a microcomputer should include the needs for present and future expansion. Therefore, a PC compatible system, such as the Little Board/86 or GRID computer is recommended.

The PC/AT compatible, with a high capacity hard disk drive and a floppy disk drive, is proposed for the dispatch unit computer. The keyboard and the mouse or the lightpen in a dispatch unit must support the required functions. The CRT display along with an appropriate graphics board at the dispatch unit should support the following characteristics: high resolution, colour graphics, and fast refresh buffer cycle.

The data communication unit in each mobile unit is an off the shelf modem with a minimum data rate of 1200 baud. The data communication unit in the dispatch unit is also an off the shelf modem with a minimum data rate of 1200 baud which is interfaced to a separate microprocessor. The required microprocessor is a PC (XT/AT) compatible with a hard disk and a floppy disk drive without a keyboard and a CRT display. The Westar Production Monitor and Control System (PMCS) is an implementation of the above.

FIGURE 3-3. AVL MINING SYSTEM
HARDWARE COMPONENTS



3.3 Positioning Sensors.

The satellite positioning sensors proposed here are two Global Positioning System (GPS) , (Trimble 4000S), one located a the dispatch site and the second in the mobile unit (See Table 3-4). Due to the expense of these receivers, they will be demonstrated for a period of approximately one month.

The second positioning system to be demonstrated is terrestrial radio navigation. The system will either be a Del Norte Trisponder or a Motorola Mini Ranger System (5 - 9 GHz) and the positioning will be done in an active ranging mode. It will also be configured in the hyperbolic mode for some of the testing to prove out the concept of unlimited user (e.g. unlimited trucks or vehicles) and passive positioning (e.g. beacon) which will be essential characteristics of the final commercial system. Several other frequency systems were considered and rejected as the accuracy was insufficient or the per unit cost per system too high (see Table 3.5 through Table 3.8 for details). Loran - C for example is a 100 kHz system which is a ground wave system with expensive transmission equipment and insufficient accuracy. The 2 MHz systems such as ARGO and Hyper-Fix which are again ground wave systems have sufficient accuracy but a unit cost that would be prohibitive. If available the Syledis system at 400 MHz would be suitable for conceptual proving but at this time their is no low cost possibilities for such a system.

All these positioning sensors are input to the microprocessor of each mobile unit. The dispatch unit receives the result of calibrated and computed real-time positions which are performed by each mobile unit microprocessor.

Technically we are confident the proposed sensors provide the accuracy and the flexibility to operate in any mine environment interdependent of the mine conditions or specific layout. However these sensors have not been utilized in an environment as brutal on hardware components as the mining vehicles. The premise that proper shock and vibration mounting of the sensors in the vehicles will be adequate to supply system reliability will be tested early in the program.

FIGURE 3-4. POSITIONING SENSORS

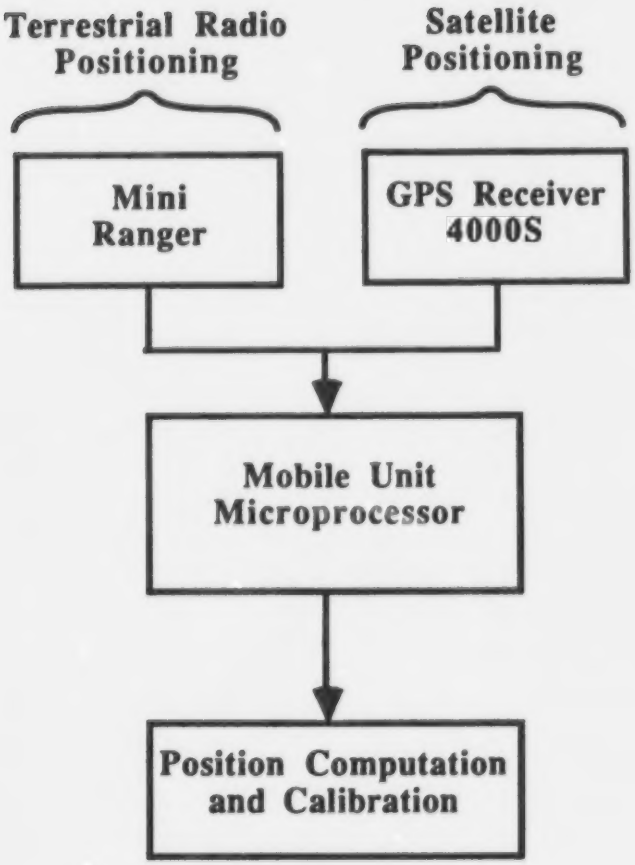


TABLE 3-5 HIGH FREQUENCY

SYSTEM	PRINCIPLE	MODE	NO. OF USERS	OPERATING FREQUENCY	RESOLUTION	MEASUREMENT ACCURACY	MAX RANGE	SPECIAL CHARACTERISTICS
ARTEMIS	Mutually tracking antennae microwave ranging	Range/Bearing	single	9 GHZ	0.1 m B mode 1 m A mode	1.5 m 2' arc	15 km 30 km optional LOS	Only one shore station req.
AUTOTAPE	Phase comparison	Range-Range	single	3 GHZ	0.1 m	0.5 m $\pm$ 10^{-6}•range	150 km LOS	Two-way voice communication- sequential range measurement on 3 channels
MINIRAN	Precision Microwave Ranging	Ranging	6 normal 22 theory	3 GHZ	1 m	2 m	45 km LOS	Simultaneous interrogations and replies possible
MINIRANGER III	Pulse Measurement	Range-Range (Rho-theta optional)	10 time sharing	5 or 9 GHZ	1 m	3 m	37 km 185 km optional LOS	Manufacturer can tailor a system to users needs (over 100 options)
SYLEDIS	Pulse Measurement	HYP. Range-Range- HYP.	unlimited 4 R-R	420 MHZ	0.1 m	1 m	120 km LOS	Low maintenance requirements
Telluro-meter	Phase Comparison	Range-Range	single, 3 with time sharing	3 GHZ	0.1 m	1.5 m 0.5 $\pm 3 \times 10^{-6}$•range	250 km LOS	Two-way voice communication
TRIDENT III	Pulse Measurement	Ranging	50 max 4 simultaneous interrogations	400 MHZ or 600 MHZ or 1300 MHZ	1 m	3 m	250 km LOS	Simultaneous coded pulses are sent to 2, 3 or 4 shore stations
TRISPONDER	Pulse Measurement	Ranging	4 with time sharing	9 GHZ	0.5 m	3 m	80 km LOS	Multi-tracker configuation capable of tracking 30 moving targets.

TABLE 3-6 MEDIUM FREQUENCY

SYSTEM	PRINCIPLE	MODE	NO. OF USERS	OPERATING FREQUENCY	LANE WIDTH	RESOLUTION	MEASUREMENT ACCURACY	MAX RANGE NM DAY	MAX RANGE NM NIGHT	SPECIAL CHARACTERISTICS
ARGO	Phase Comparison	Range-Range HYP (optional)	12 w/2 Ranges 9 w/3 Ranges 7 w/4 Ranges	1.6-2 MHZ	75-94 m	.01 Lane	1.4 m	740	408	Non-Ambiguous only if lane count ± 5 lanes
DECCA 12f Landa	Phase Comparison	Range-Range Rho-Rho	Single R-R Unlimited with f std. (Rho-Rho)	150 KHZ	200-600 m	.01 Lane	36-100 m	650	350	Lane ident. feature only in Range-Range Mode, large shore stations required.
HI-FIX/6	Phase Comparison	HYP Range-Range R-R-HYP	4 R-R HYP Unlimited	1.6-5 MHZ	75 m	.01 Lane	5 m	370	370	Non ambiguous with coarse lane option, multi-plexed carrier uses time sharing
HYDROTRAC	Phase Comparison	HYP Range-Range	Single R-R Unlimited HYP	1.6-3 MHZ	50-93 m	.01 Lane 0.8 m	unk.	460	230	Non ambiguous only with integrated system or with option, 4 R-R users under development
LORAC	Phase Comparison	HYP Range-Range	Unlimited	1.6-2.5 MHZ	83 m	.001 Lane	15-40 m	480	165	HYP lane Ident option, cesium beam frequency std. req. for R-R mode
MAXIRAN	Precision Microwave Ranging	Ranging	6 practicle 22 theory	420-450 MHZ	none	1 m	3 m	650	650	Non-ambiguous, uses pseudo random coded pulse and time sharing, linear amplifier required for extended range coverage.
OMI SYSTEM	Phase Comparison	Range/Range/HYP	unlimited	1.6-1.8 MHZ	183 m	.001 Lane 0.2 m	1 m	480	280	Non-ambiguous, phase measurement with cesium beam clock, completely portable
RAYDIST	Phase Comparison	Range-Range R-R-HYP HYP	4 R-R 4 R-R-HYP HYP unlimited	1.6-3.3 MHZ	45 m	.01 Lane 0.5 m	3 m	480	280	Non-ambiguous only with multiple LOPS and integrated system
TORAN	Phase Comparison	HYP	Unlimited	1.6-3.0 MHZ	40-90 m	.01 Lane 0.4-0.9 m	1 m	550	250	Non-ambiguous only with special option

TABLE 3.7 - LOW FREQUENCY AND SATELLITE

GPS System	Phase & PRN Code Principle	Pseudo Range Mode	Unlimited No. of Users	1.3 & 1.6 GHz Operating Frequency	1 cm Resolution	10 cm - 100 m Measurement Accuracy	Global Max. Range	In Development Fully Operational in 1992 Special Characteristics
LORAN-C	Pulse and CWPC	HYP Rho-Rho	Unlimited	100 KHz	25 m	50 m	2000 km	Gov't maintained shore stations
NNSS	Frequency Comparison - Integrated Doppler-count	Range Difference	Unlimited	150,400 MHz	5 Doppler Counts	100 m One good Fix	Global Coverage	Intermitent, Frequency of Fix Information increases with latitude, Satellites U.S. Gov't maintained, Resolution applies to instrument not measurement.
OMEGA	CWPC	HYP Rho-Rho	Unlimited	10-30 KHz	500 m	1.5 km	10,000 km	Only stop gap positioning system, not accurate enough for survey applications.

3.4 Mobile Unit Software

The software needed for each mobile unit microprocessor is composed of initialization, position calibration and computation, and communication modules (Figure 3.8).

Initialization is the process of establishing the starting positions and setting up one day operation. Then the mobile unit may start its operation and send its real-time position and other information such as the mobile unit's status, etc. The frequency of this tranmission is at a fixed time interval or when a request is made by the dispatch unit.

A communication module is used to transmit and receive information (e.g. position, instruction, etc.) to and from the dispatch unit. Pulsearch will interface to the digital communication system that WENCO choses by using one of the output slots of the on-board processor.

3.7 Dispatch Centre (Control Centre) Software

The software needed in the dispatch unit of the designed mining system is composed of initialization, dispatch allocation, communication, and graphics modules (Figure 3-9).

Initialization is the process of setting up one day's operation with each mobile unit at the start of each working day. During this process the dispatch centre will verify the status of each vehicle. Corrections or updates will be made as required at periodic intervals.

The communication module takes care of sending and receiving information (e. g., instructions, position, etc.) to and from mobile units.

Figure 3-8. AVL MINING ' SYSTEM MOBILE UNIT SOFTWARE

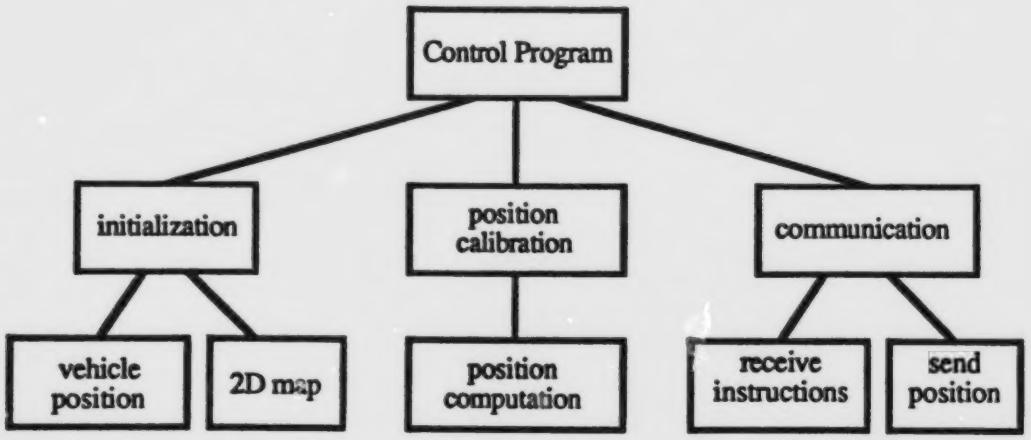
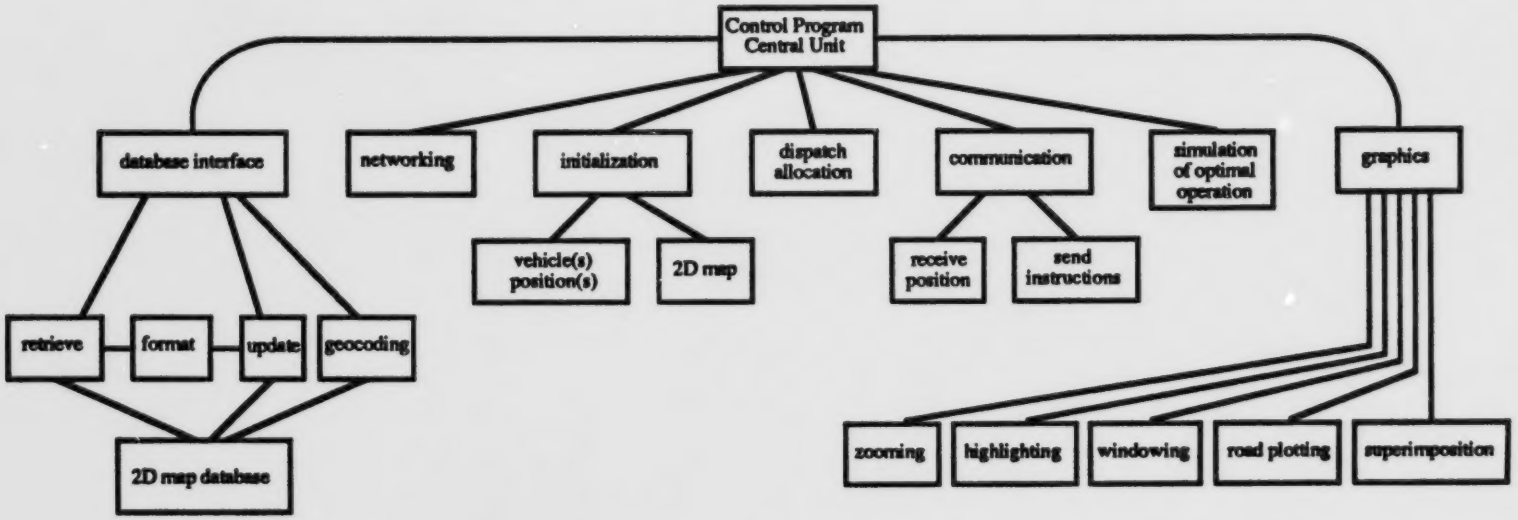


FIGURE 3-9. AVL MINING SYSTEM DISPATCH UNIT SOFTWARE



3.6 Display System - Map Database

The map required in the display system for an open pit mine is a 2D map of the entire mining operation. The map database in its entirety is stored and updated in the dispatch or central unit. The 2D map of the entire mining operation is plotted on a CRT display screen in the dispatch unit to enable the operator(s) to monitor the mine operations visually.

The graphics module is a collection of functions to handle output graphics for the CRT display. Its functions include zooming, high lighting, windowing, road plotting, and superimposition of the mobile units' positions on the screen.

4. PROJECT PLAN

4.1 Project Personnel

The Key staff assigned to conduct the project are outlined below with their assigned functions on the project. All staff are either permanent employees of Pulsearch or the University of Calgary. The personnel resumes for the principles have been previously provided and all resumes are available on request.

Project Administrators	- E.J. Krakiwsky
	- J.R. Adams
Software Engineers	- K. Hassan
	- T. Porter
	- J.F. McLellan
	- C. Harris
	- L. Klesh
Systems Engineers	- R. Hay
	- J.W.K. Smith
	- N.J. Rushton

4.2 Work Plan and Schedule

It is estimated that the Phase 1 development will take place from January 1,1989 to June 30,1989 and that the Phase 2 development will take place from July 1, 1989 to June 30,1990 to be consistent with the previous projections provided by WENCO. This schedule can be revamped once the final mine and overall schedule is set by WENCO.

5. FINANCIAL

5.1 Fee Structure

Labour

The labour rates given below cover the people to be assigned to this project.

Project Administrator	$ 500.00 per day
Software Engineer	$ 360.00 per day
Systems Engineer	$ 360.00 per day

Equipment Rates

The equipment required on the project would be purchased at the beginning of the project as a direct project disbursement at documented cost plus 10 percent.

Disbursements

The disbursements for the project will be charged at documented cost plus 10 percent. These costs include travel, living expenses and other incidental expenses incurred.

5.2 Cost Estimate

The cost summary is as outlined below noting that no labour or disbursements related to the deployment of the navigation and display system at the mine site have been estimated as the mine site has not been chosen nor the evaluation period fixed.

Phase 1

E.J. Krakiwsky Consultants	$15,000.00
U. of C. Students	$20,000.00
Pulsearch	$20,000.00
Disbursements	$20,000.00
Total Phase 1	$75,000.00

Phase 2

E.J. Krakiwsky Consultants	$20,000.00
U. of C. Students	$ 5,000.00
Pulsearch	$40,000.00
Disbursements	$10,000.00
Total Phase 2	$75,000.00
TOTAL PHASE 1 & PHASE 2	$150,000.00

5.3 Terms and Conditions

Pulsearch will invoice monthly on a time and materials basis. All invoices are due in thirty days from receipt of invoice. An interest rate of two percent (2%) will be charged on the outstanding balance.

APPENDIX 1

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APPENDIX VIII

DATA BASE, DETAILED ANALYSIS

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9 August 1988

Memo: to File

Sj: Data Base - Possible Candidates

This memo updates the memo of 12 July 1988. It discusses the general attributes of the Relational Data Base Model, and compiles a list of possible candidates for consideration for use in the CANMET Integrated Truck/Shovel Mine Management System.

Introduction:

The Relational DataBase Model, A brief General Discussion: The attributes of a Data Base implementation are expressed in a number of different theoretical models. An approximate categorization of the most predominant of these models used in today's data processing practise are:

- Multiple Key Models
- Hierarchical (DL/I) Models
- CODASYL DBTG Models
- Relational Models

Any given data management product may have attributes described in one or more of these models. A data management (or data handling) system is often described by associating it with the data base model which has the greatest number of attributes fully or partly reproduced in the product. Thus, DEC's RMS and DG's INFOS are said to be Multiple Key Models while Prime's DBMS is said to be CODASYL compliant.

The relational data base model differs in several fundamental aspects from the others.

> " For one, the relational model is based on a foundation of theory from relational mathematics. Another difference is the relational model is more abstract. DL/I and DBTG are directed at programming systems. ... The relational model consists of a set of concepts that are not particularly related to any programming language.
>
> Finally, the relational model tends to represent data as it exists. The DL/I model requires data to be represented by hierarchical constructs, and the DBTG model requires the use of the set concept. The relational model does not force the use of an artificial construct; rather, it reduces data relationships to simpler components and represents the components directly." (1)

In general terms, most data structures can be represented more easily and succinctly in the relational model. Actual implementation is somewhat impeded by the a) the immense processing load that a faithful rendition of the relational model, and its operations, places on an installation, b) the lack of truly relational products in the market place, c) the general lack of understanding on the part of data processing practioners, and users, regarding the design and operation of relational data bases, and d) the scarcity of significant user involvement in the design of application data models.

These conditions notwithstanding, relational data base concepts have increased steadily in popularity in the past few years, to the extent that "it is hard to find a vendor that does not claim its DBMS is relational." (2) In spite of manufacturers claims, most of the products offered as relational DBMS's are not, in fact, sufficiently like the relational model to be considered as such. A product may be considered minimally relational if a) all information is stored within tables and can be manipulated in these tables without reference to other structures (ie: schemas , keys, etc.), and b) if the basic relational operators (select, project, and join) each produce a new table by combining one or more tables.

" By these definitions, dBase and R:base are not relational database managers. The dBase program does not allow direct manipulation of tables but requires the use of work areas in order to relate tables. To gain acceptable performance, the user or programmer must explicitly reference the indexes on these tables. R:base provides relational operators, but does not allow the user or programmer to reclaim the space without repacking the database. Since every relational operator creates a table, this makes it impractical to use R:base as a relational database manager. Most R:base programmers relate tables through the use of pointers, which is not necessary in a minimally relational database system." (2)

It is important to note that, while the use of relational concepts (or constructs) permits the extremely concise expression of data relationships, there is no inherent saving in computer processing resource required to carry out the specified operations. In actual fact, quite the opposite is true. Relational data bases typically are found to be very demanding of CPU cycles, memory, and disk storage. Especially in the presence of large bodies of data, or poorly designed applications.

Evaluation:

The following products are offered for sale as relational data base systems. They are considered here as candidates for use in the CANMET Integrated Truck/Shovel Mine Management System. The guidelines for the use of the Data Base with the Management System are set out in the memo LJT to File(CANMET) dated 28 June 1988.

Clipper
DB2
Dbase 3 PLus
Emerald Bay
FoxBase
Informix
Ingres
Oracle
Paradox
PC Focus
Revelation
SQLBase
Sybase
XDB
XQL

The following attributes are to be identified for the candidate packages:

SQL: Does the DBMS support a 'Structured Query Language' interface? Specifically, does the interface meet the ANSI Level 1 implementation of SQL? (YES | NO | ?)

Mini Compatibility: Does the DBMS have a compatible mini-computer implementation?

Main Frame Compatibility: Does the DBMS have a compatible main frame implementation?

Network Support: Can the DBMS be networked successfully, ie: can it be installed on one node of a network, and accessed from others, and does it support file & record locking to enable many users to access it a t the same time?

Interface: Can the DBMS be interfaced to third generation languages, especially Borland Turbo Pascal. Ie: can programs written in Pascal 1) extract information from & 2) submit information to the data base(s)?

Memory Requirement: How much main memory is required for the DBMS to run in an IBM PC/AT?

Nature of the Data Base: Is the data base of a relational nature, hierarchical nature, network nature, or other.

Supplier: Who makes it?

Distributor: Who sells it (Especially Locally)?

Price: In $Canadian

In so far as information has been available, or has been forthcoming from manufacturers or distributors, it has been summarized in the attached evaluation analysis.

Recommendations:

Reviewing the published literature and company supplied promotional and technical literature of as many of the above listed products as possible, it has become increasingly clear that the choice of data base system to be used with the Integrated Truck/Shovel Management System can be easily reduces to two products: Oracle by the Oracle Corporation, or dBase by the Ashton-Tate Corporation. The remainder of the this section deals with only these two products.

Oracle: Advantages: Oracle is recommended because it supports more hardware and software configurations than any other product in the market place. Additionally, it more closely approximates the relational offering than almost any other contender. It uses a server strategy and supports Local Area Network installations. It has a procedural language interface.

Oracle: Disadvantages: Oracle is contra-indicated for the following reasons: 1) The LANserver component of Oracle operates only under Xenix - MSDOS is specifically excluded. 2) Oracle is expensive, a minimum installtion can be expected to cost well over $5,000 with reasonable installations approaching the $10,000 mark, for Oracle Software alone. Xenix, C, etc. must also be acquired. 3) Any customized interface to the Oracle product must be created in C under Xenix. This is not compatible with the either the future or current direction postulated for development of the CANMET Integrated Truck/Shovel Management System. The procedural language interface is C only.

dBase: Advantages: Ashton-Tate's dBase III is one of the most popular and widely used data base systems in the market today. This means that there is a large body of dBase extertise in the user world. The product works in most LAN environments. It is competatively priced, with software for a typical installation costing under One Thousand Dollars.

dBase: Disadvantages: Throughput for applications in dBase oftens falls short of that observed for other data base systems. Throughput is expected to be improved with the iminent release of dBase IV. dBase III is an interpretive system. This adversely affects system reliability. It is not clear that there is any interface between procedural languages and the dBase III environment.

As a result of the information collected under this study, it is the author's recommendation that Ashton-Tate's dBase III be used as the basis for the Data Base Interface to the Integrated Truck/Shovel Management System, and that the Interface be designed in as general a method as possible to ensure the possibility of accomodating another data base product if required. It is recognized that there are several packages in the market place which are functionally equivalent to dBase III. These include Clipper, and Foxbase 2.1. The recommendation of dBase III is not intended to explicitly exclude these products, but rather, to serve as an indication of the preferred 'type' or 'class' or 'style' of data base product to be used.

Estimates:

Estimates for the implementation of a Data Base Interface to the Truck/Shovel Management System are as follows:

Item	Estimate
1. Design of Data Base, Data Definitions, etc.	40 Mandays
2. Purchase of DB Products	$800
3. Implementation of Data Base	20 Mandays
4. Development of Interfaces	40 Mandays
5. Testing and documentation of interfaces.	30 Mandays

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Last Updated: 14 July 1988

	True Relational	SQL	Compatibility Mini	Compatibility Main	Network Support	Procedural Interface	Memory Rqmnt	Server	Mfr	Dstr	Pr
Clipper	No	No									
DB2	Yes This is a main frame (IBH MVS) offering, and is the basis for Oracle.										
Dbase 3 PLus	No										
Emerald Bay	No										
FoxBase	No										
Informix-SQL 2.1	Yes	ANSI 1	Yes	?	Yes	C	640K	Yes	Informix Software		
Ingres 5.0	Yes	ANSI 1	Yes	?	?	C	640K	?	Relational Technology		
Oracle 5.1	Yes	ANSI 1	Yes	Yes	Yes	C, FORTRAN COBOL	1M(1)	Yes	Oracle Corp.		
Paradox	?								Borland	SuperSoft	
Revelation	?										
SQLBase	Yes	ANSI 1	Yes	Yes	Yes	C	640K	Yes(2)	Gupta Technologies		
Sybase	?										
XDB II	Yes	ANSI 1	?	?	?	C, COBOL	512K	?	Software Systems		
XQL 1.0	Almost	No	?	?	Yes	BASIC, C Pascal	512K	Yes	Novell Development		

Notes: (1) Uses extended memory leaving main memory mostly free
(2) SQL Server

APPENDIX IX

PROJECT SCHEDULES

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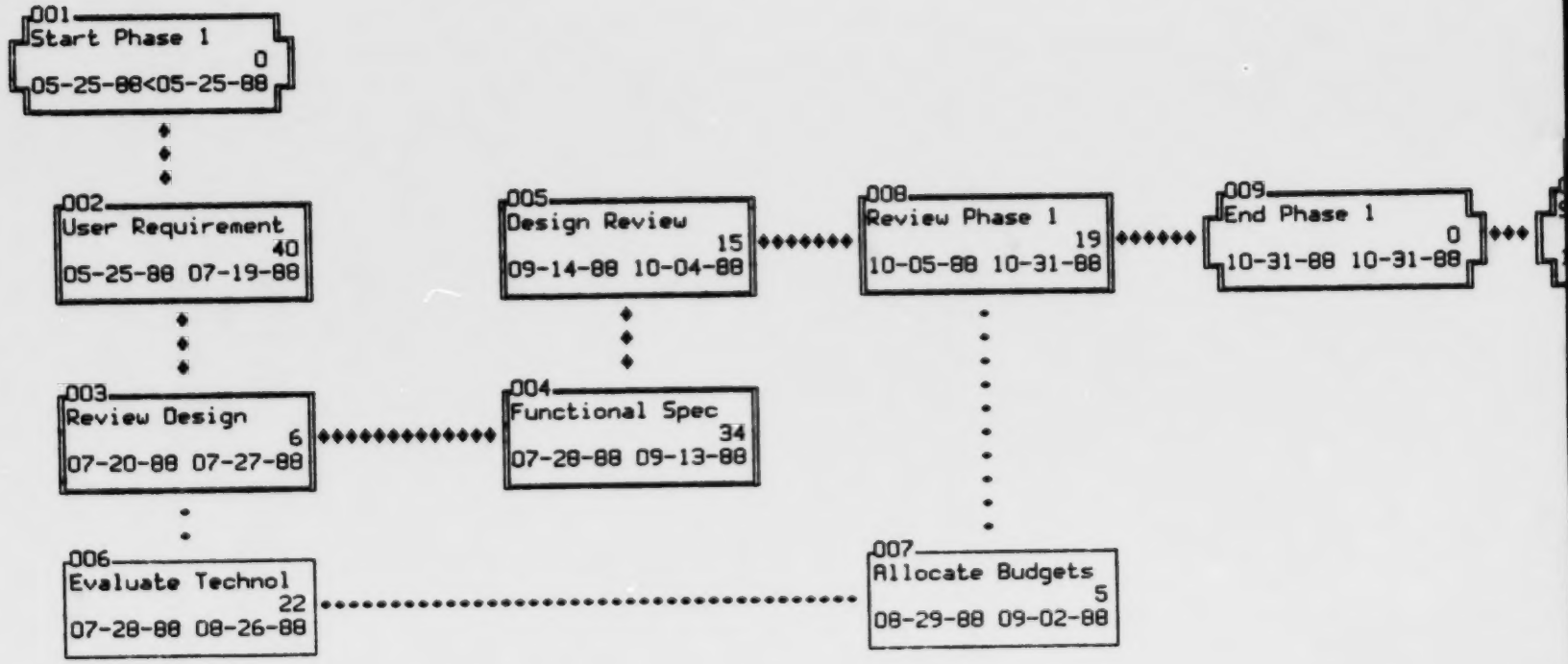
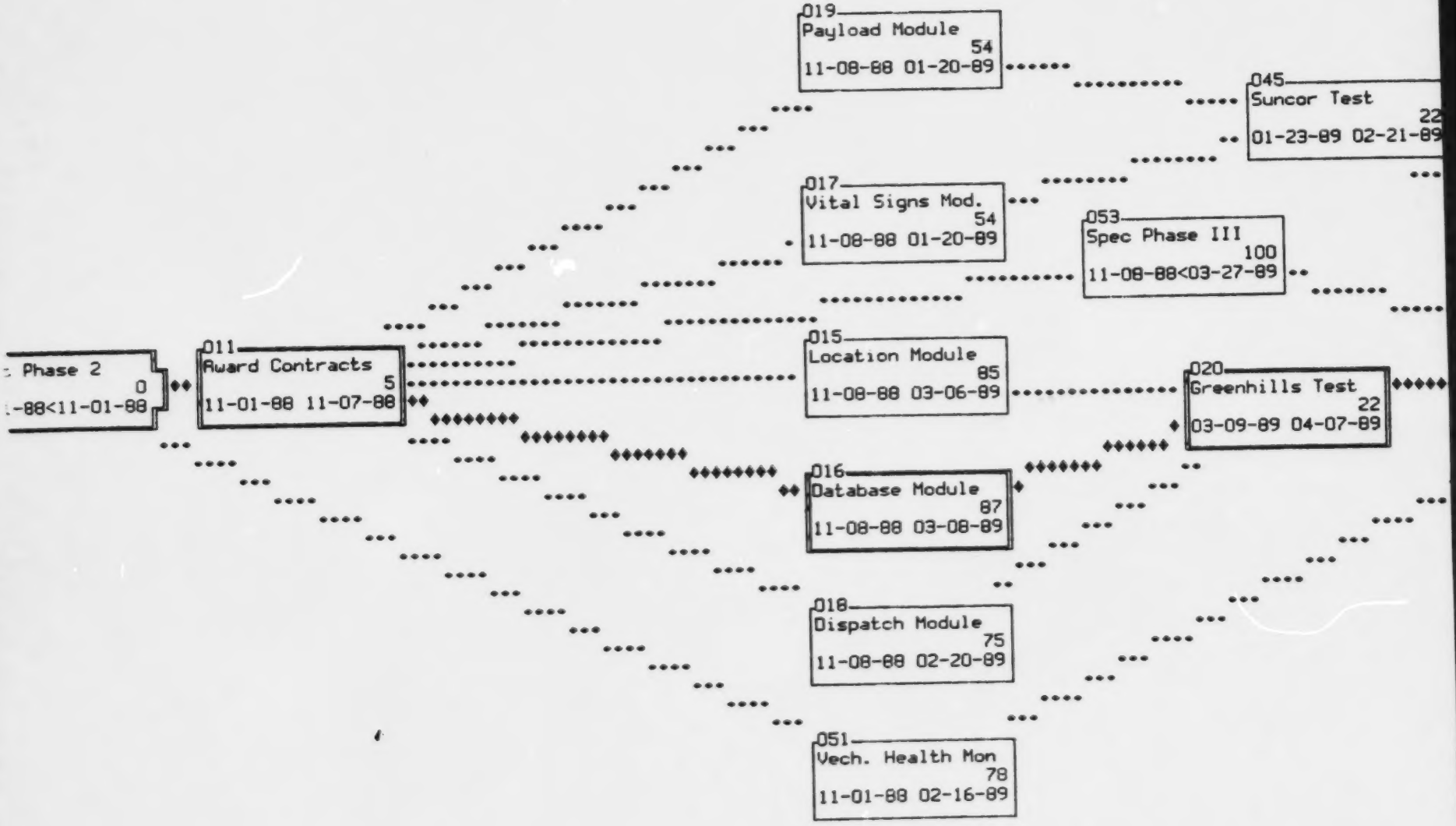
Revision: 33

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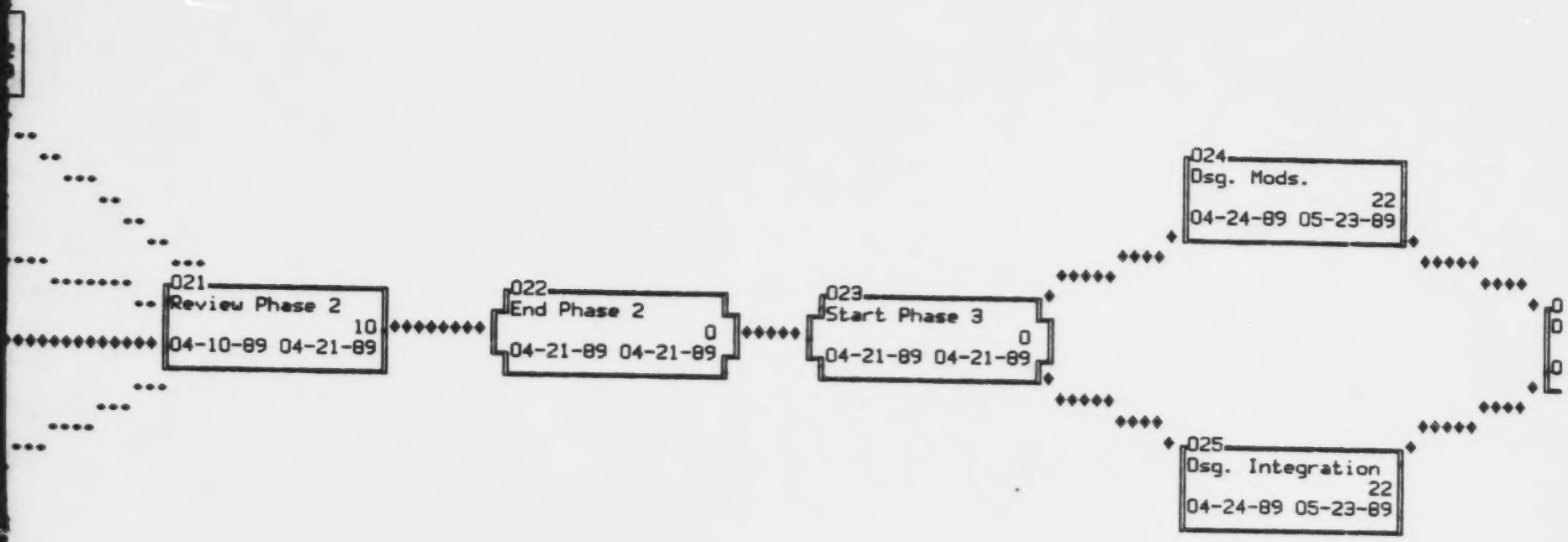
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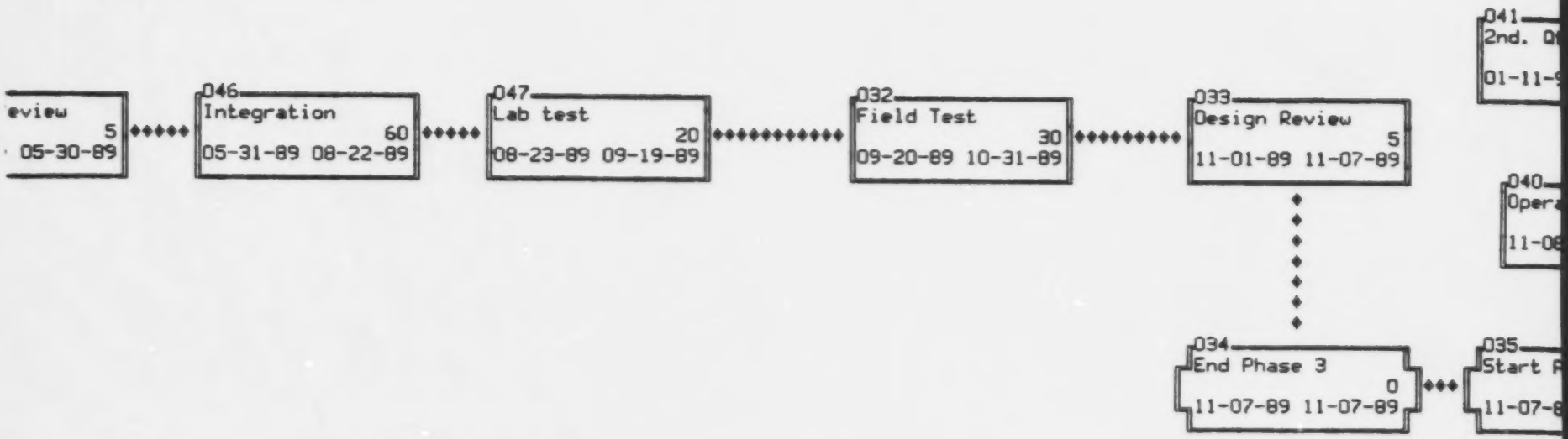
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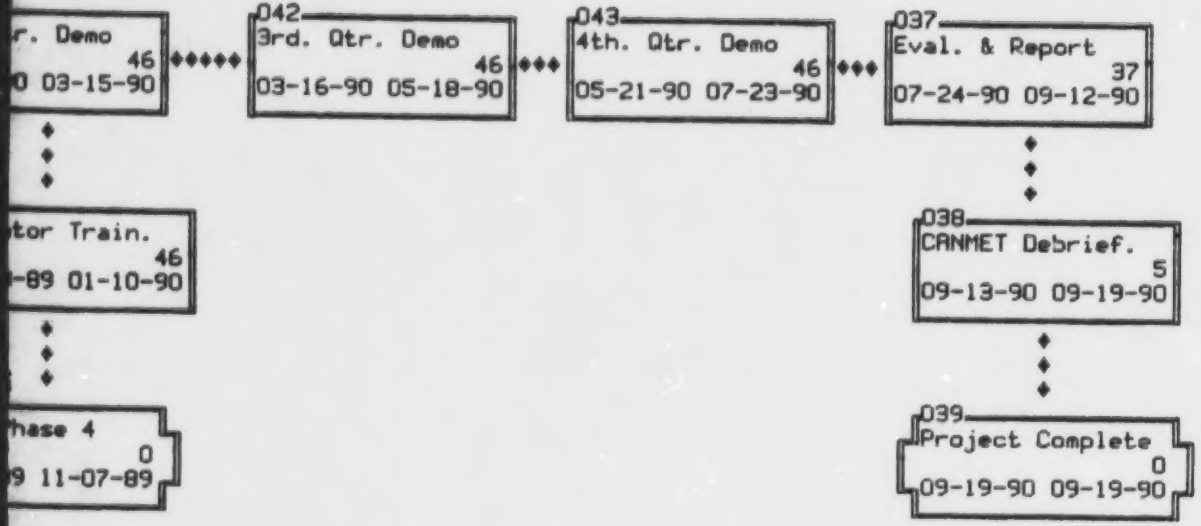
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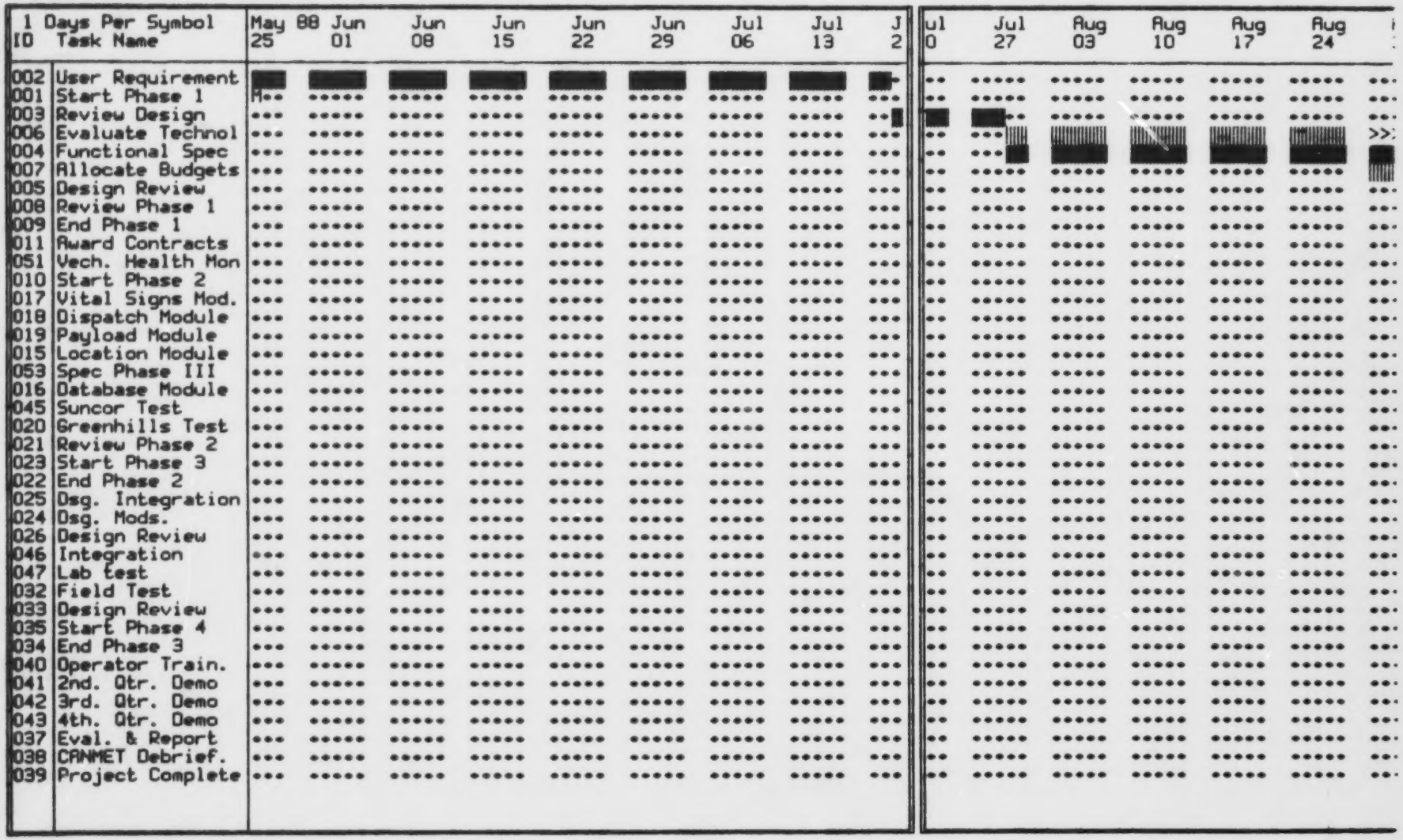

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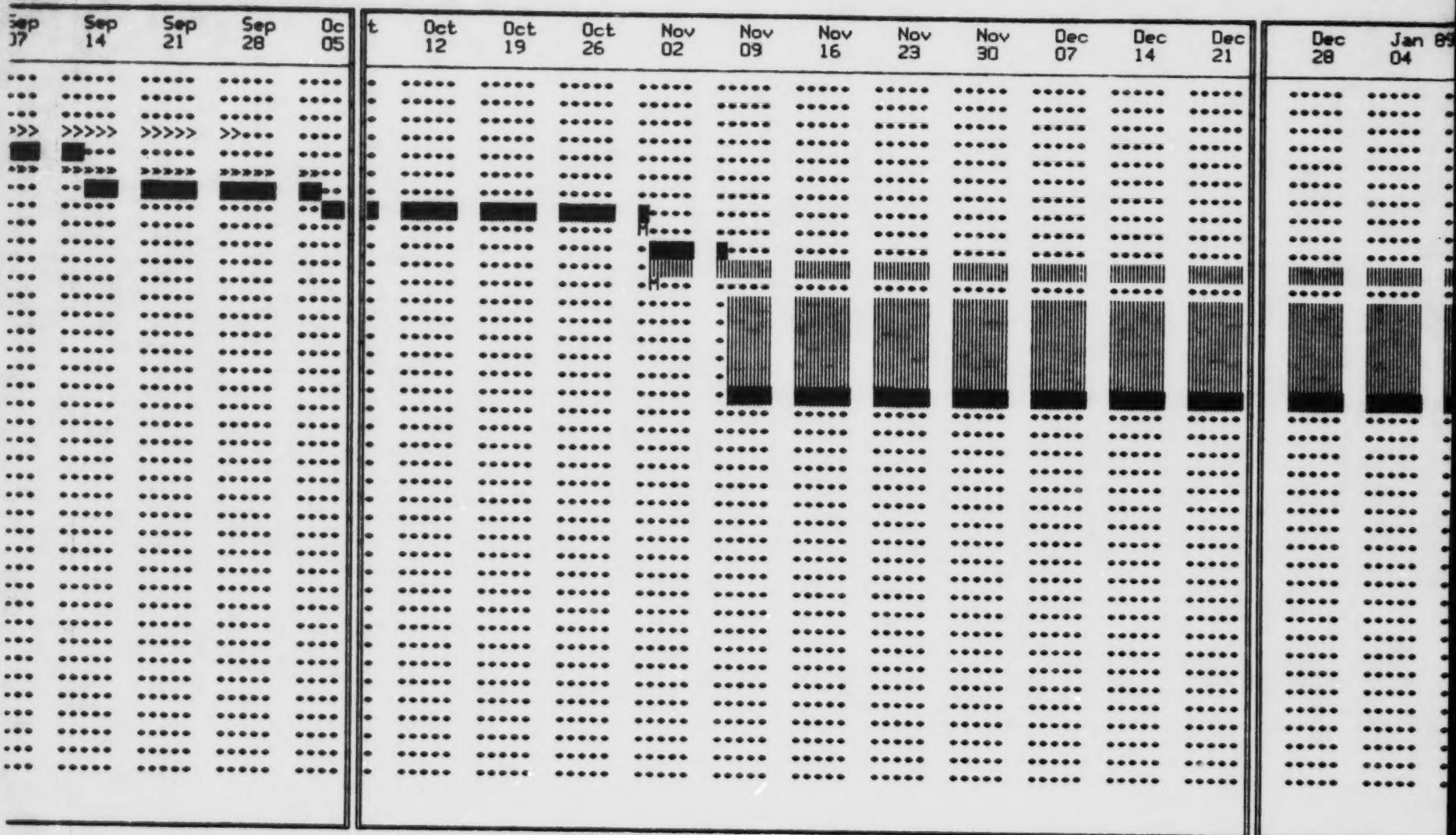
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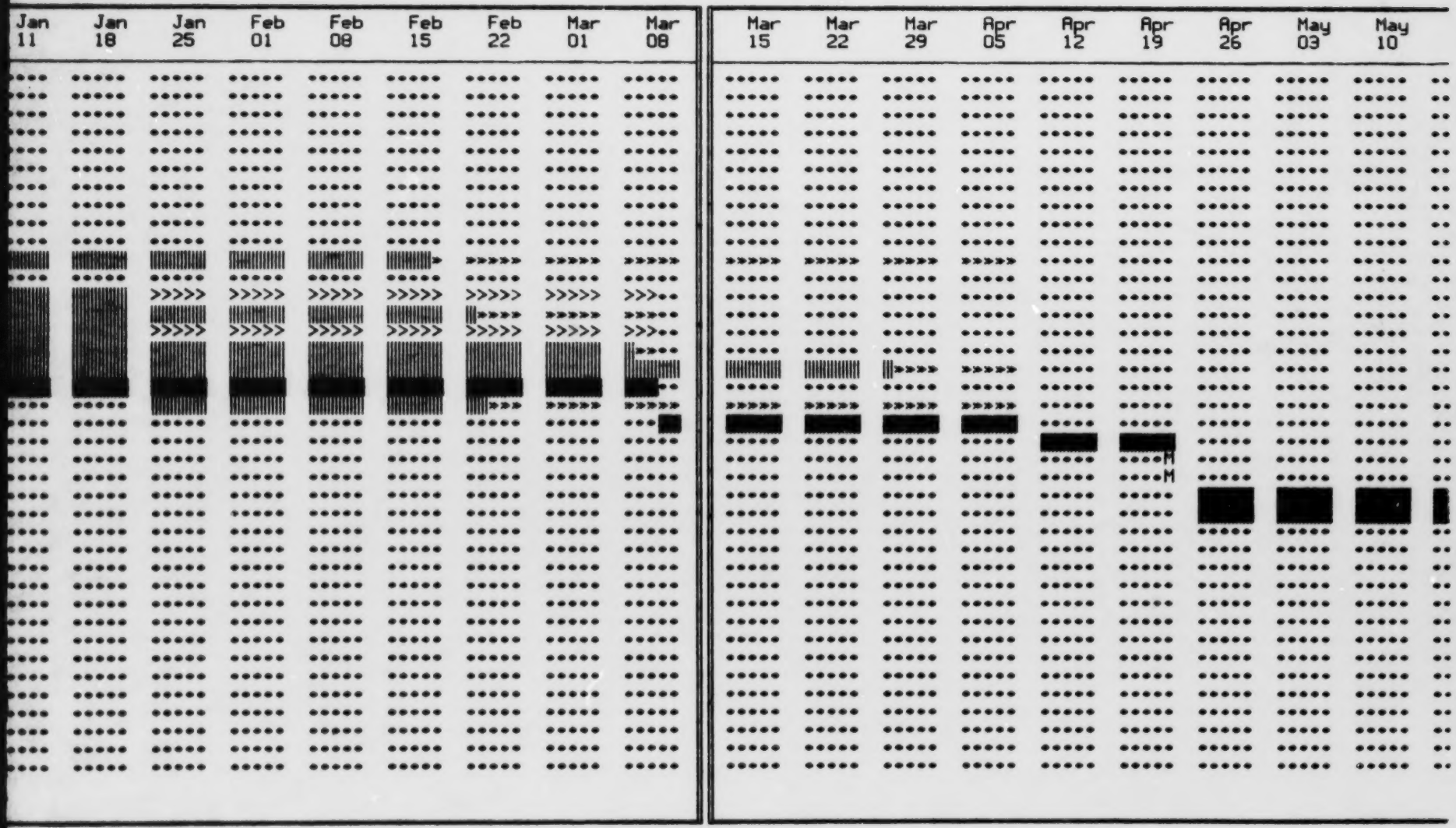
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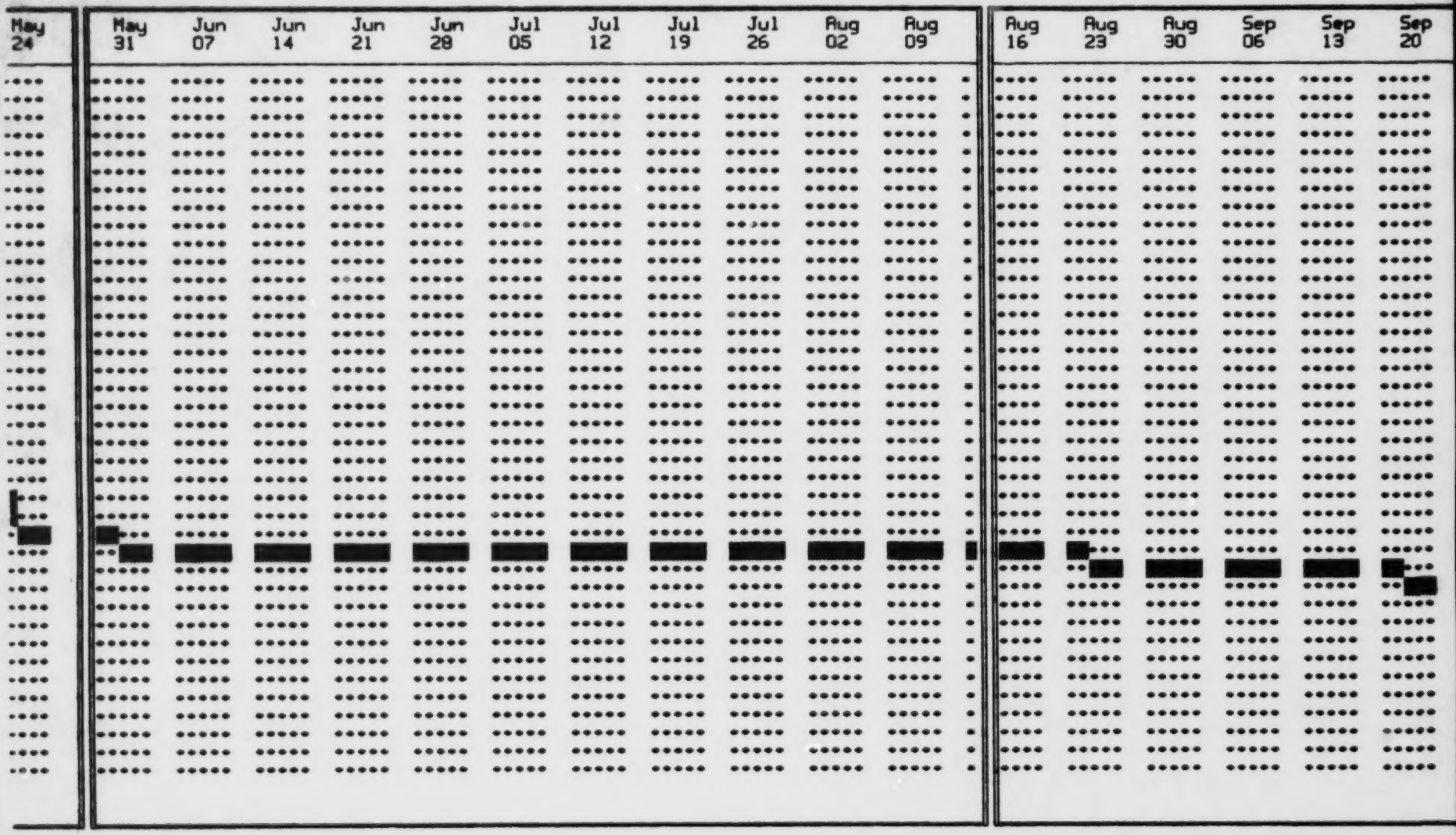
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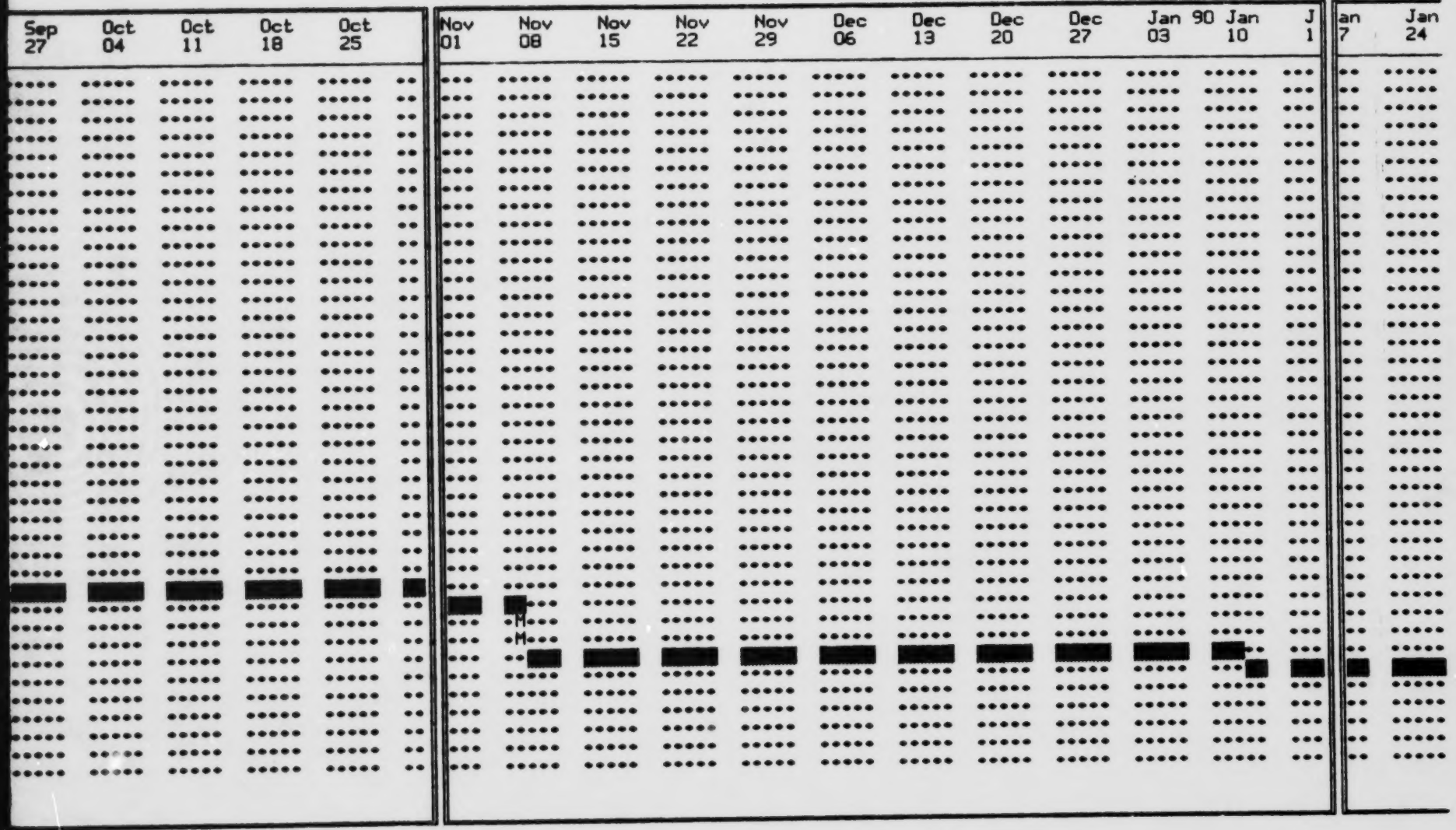
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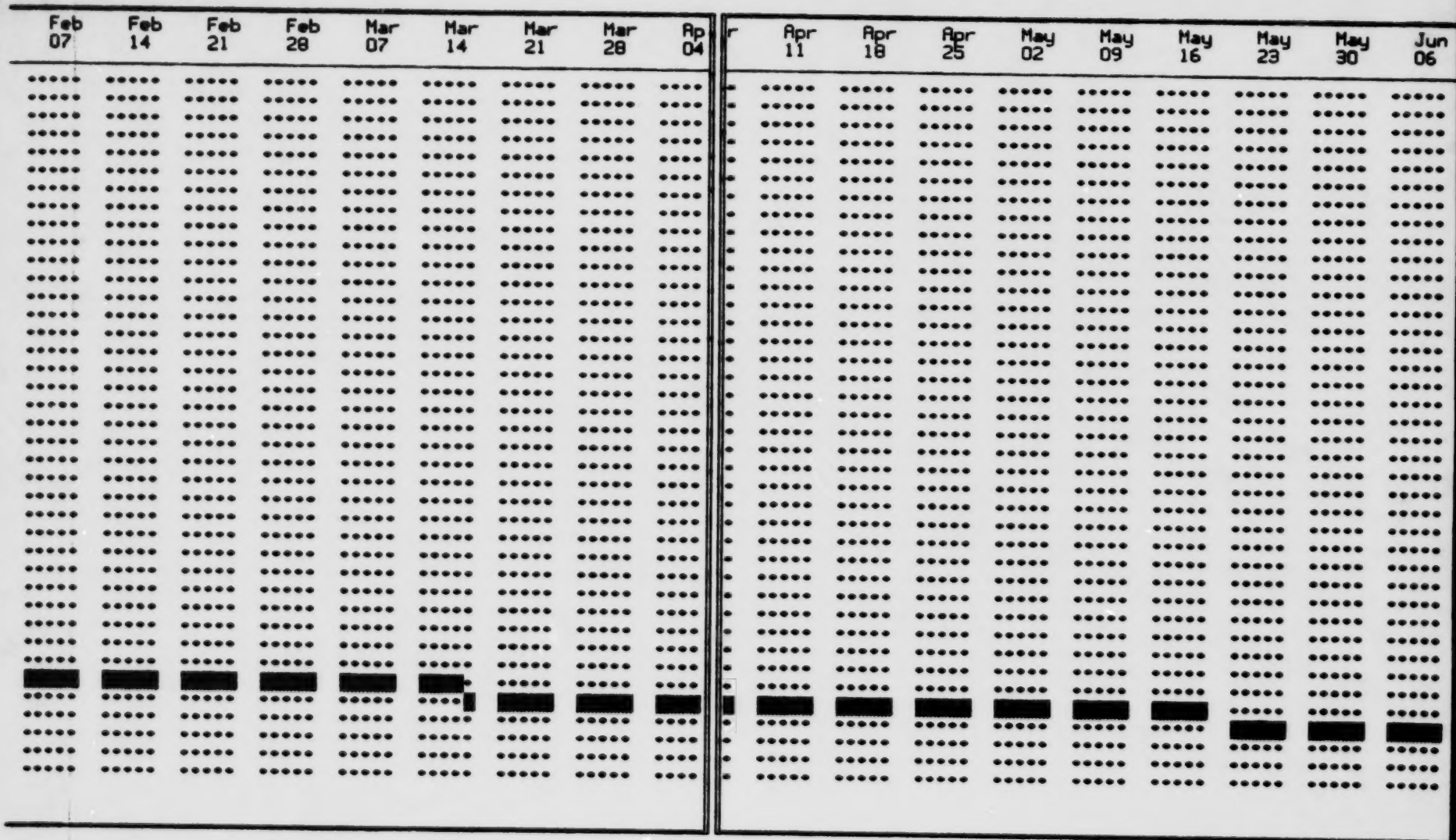
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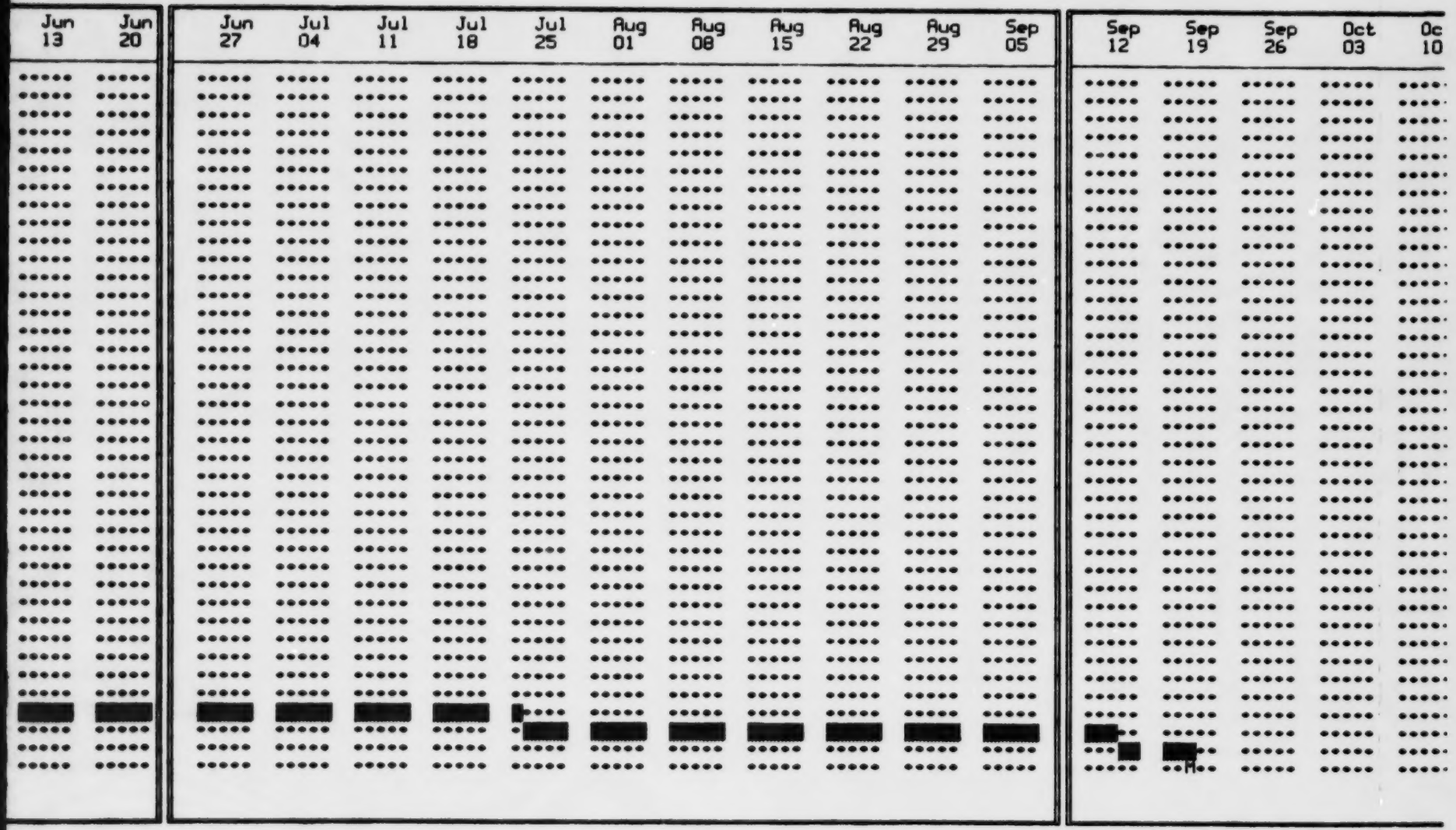
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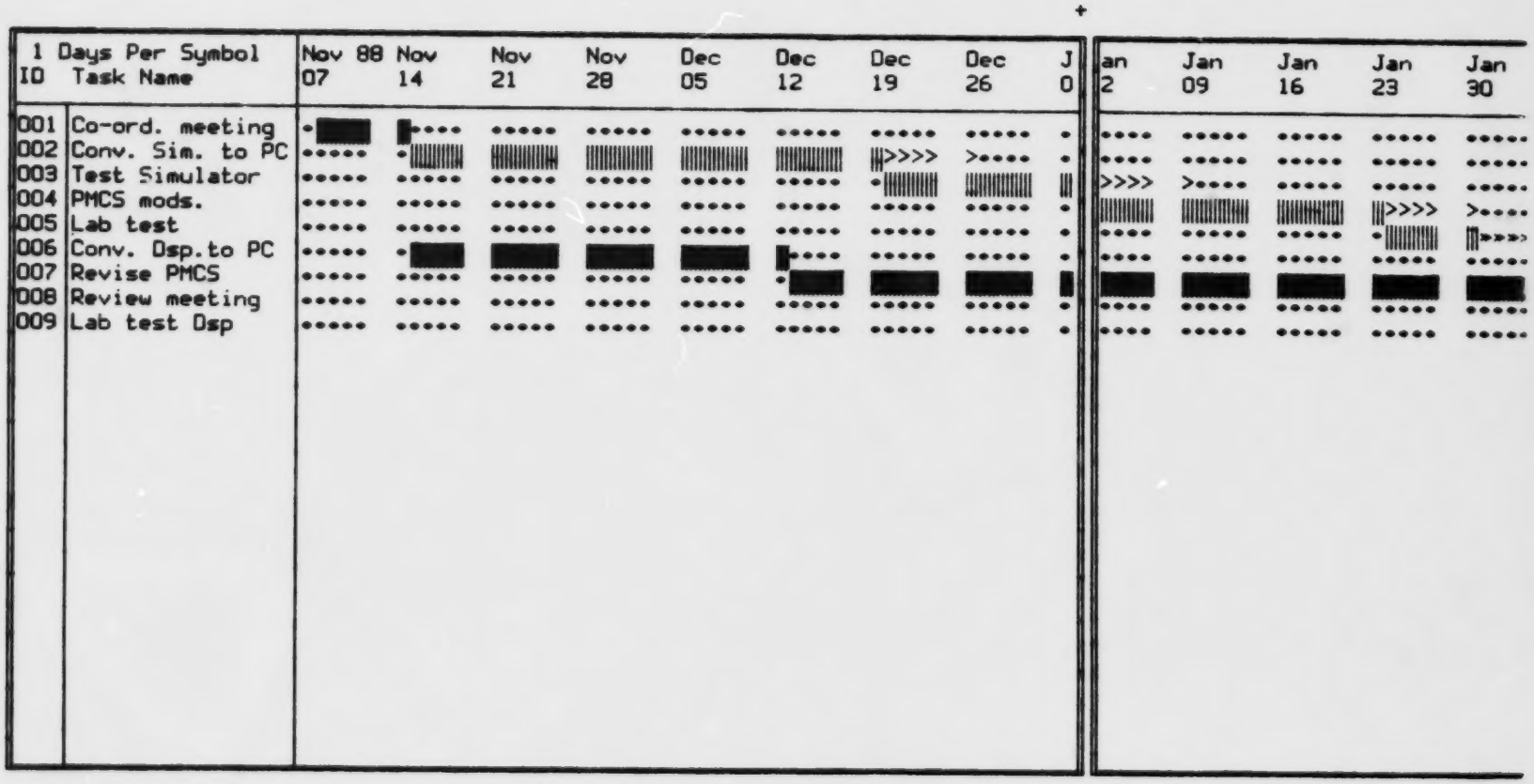

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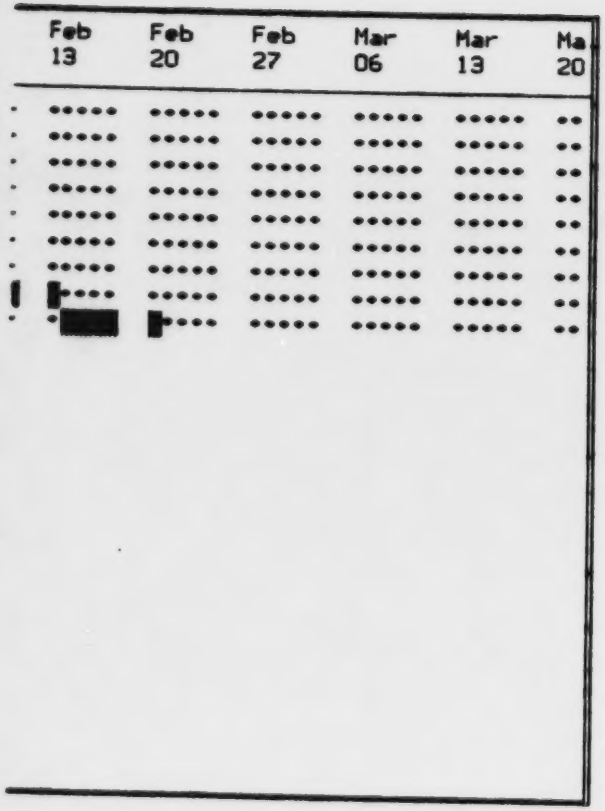
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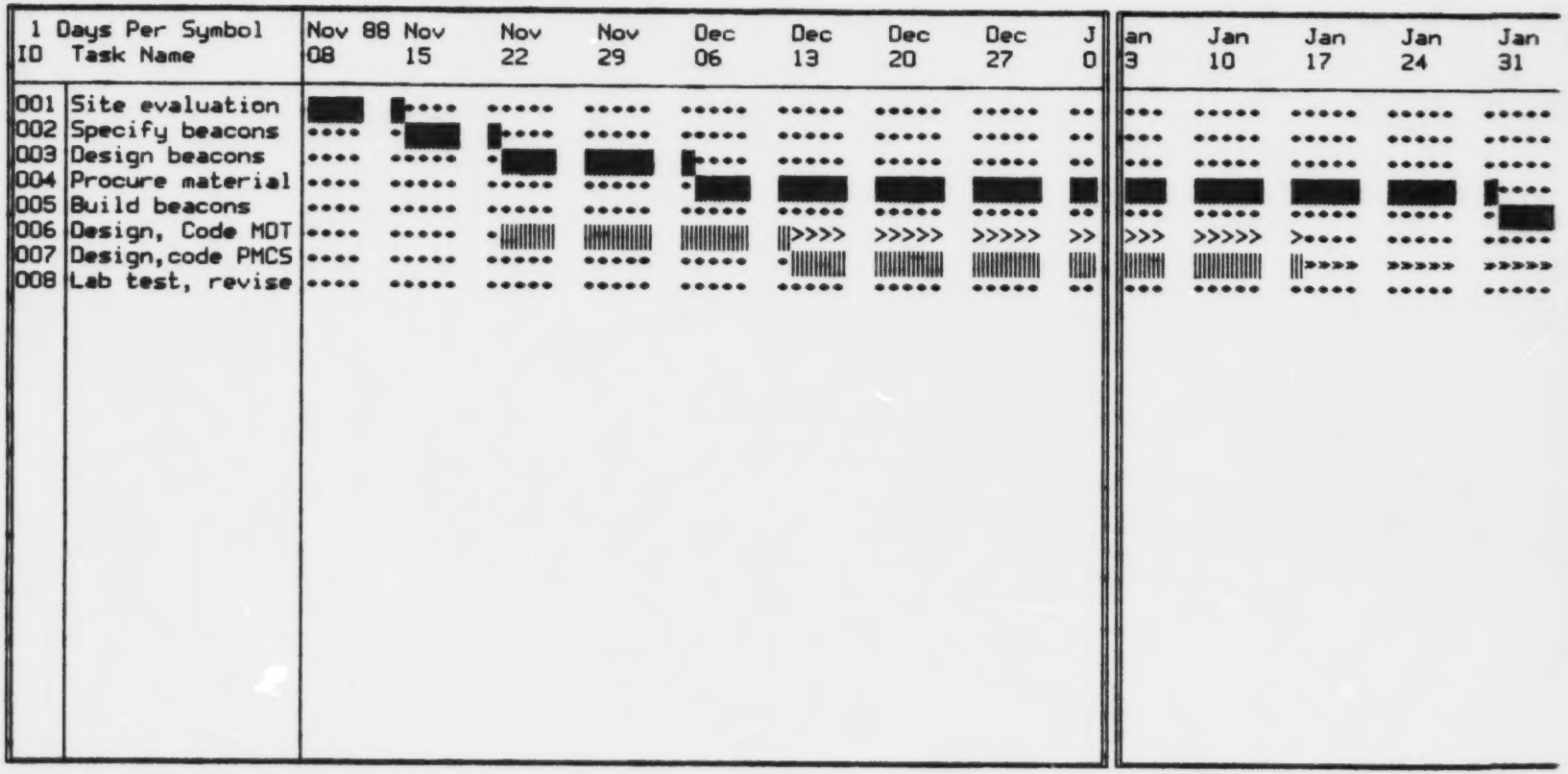

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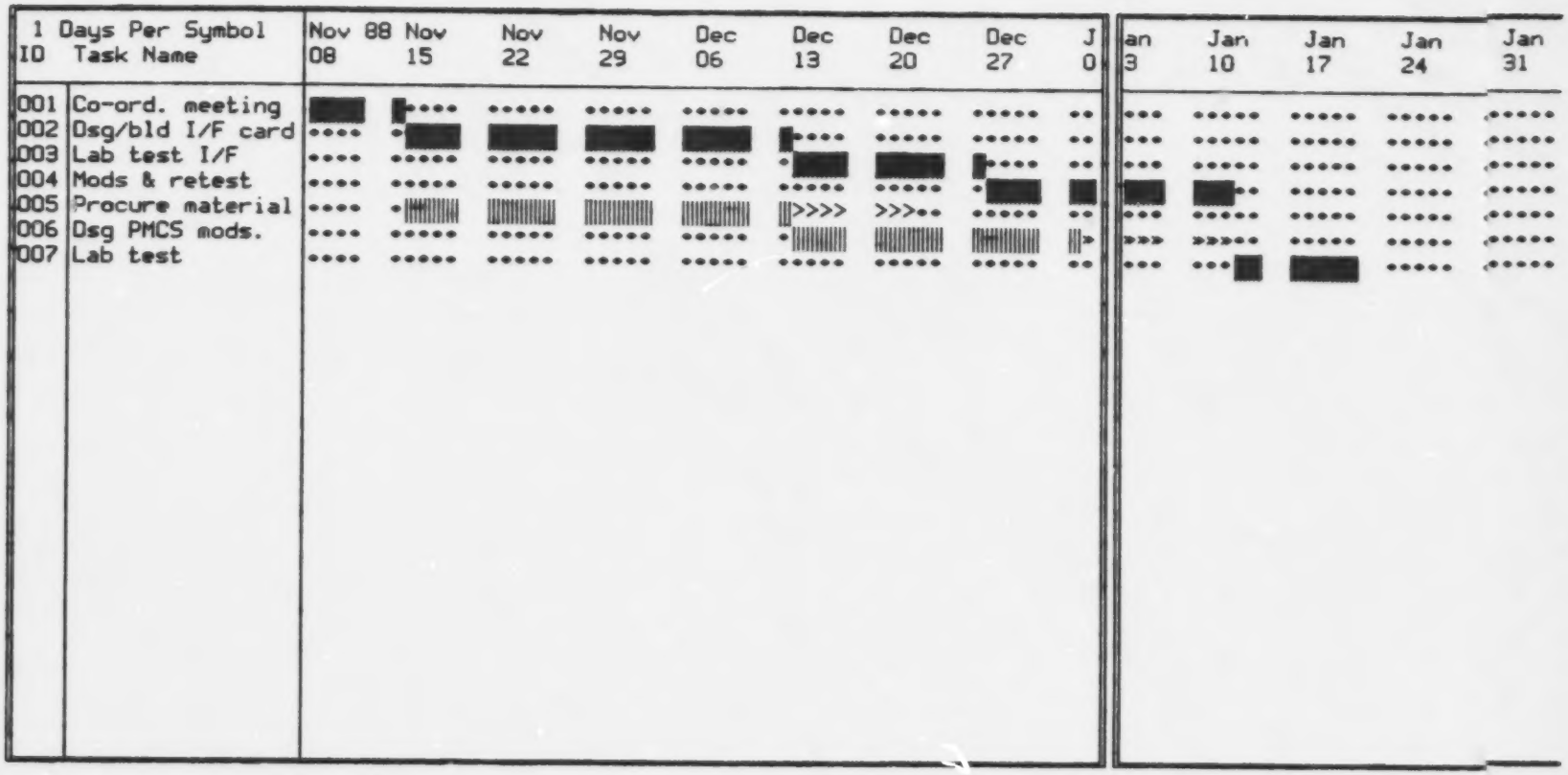

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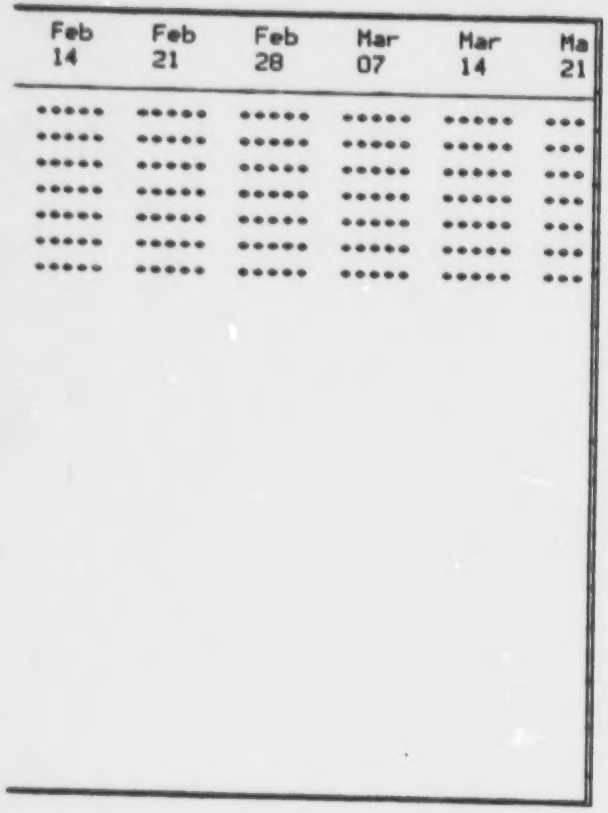
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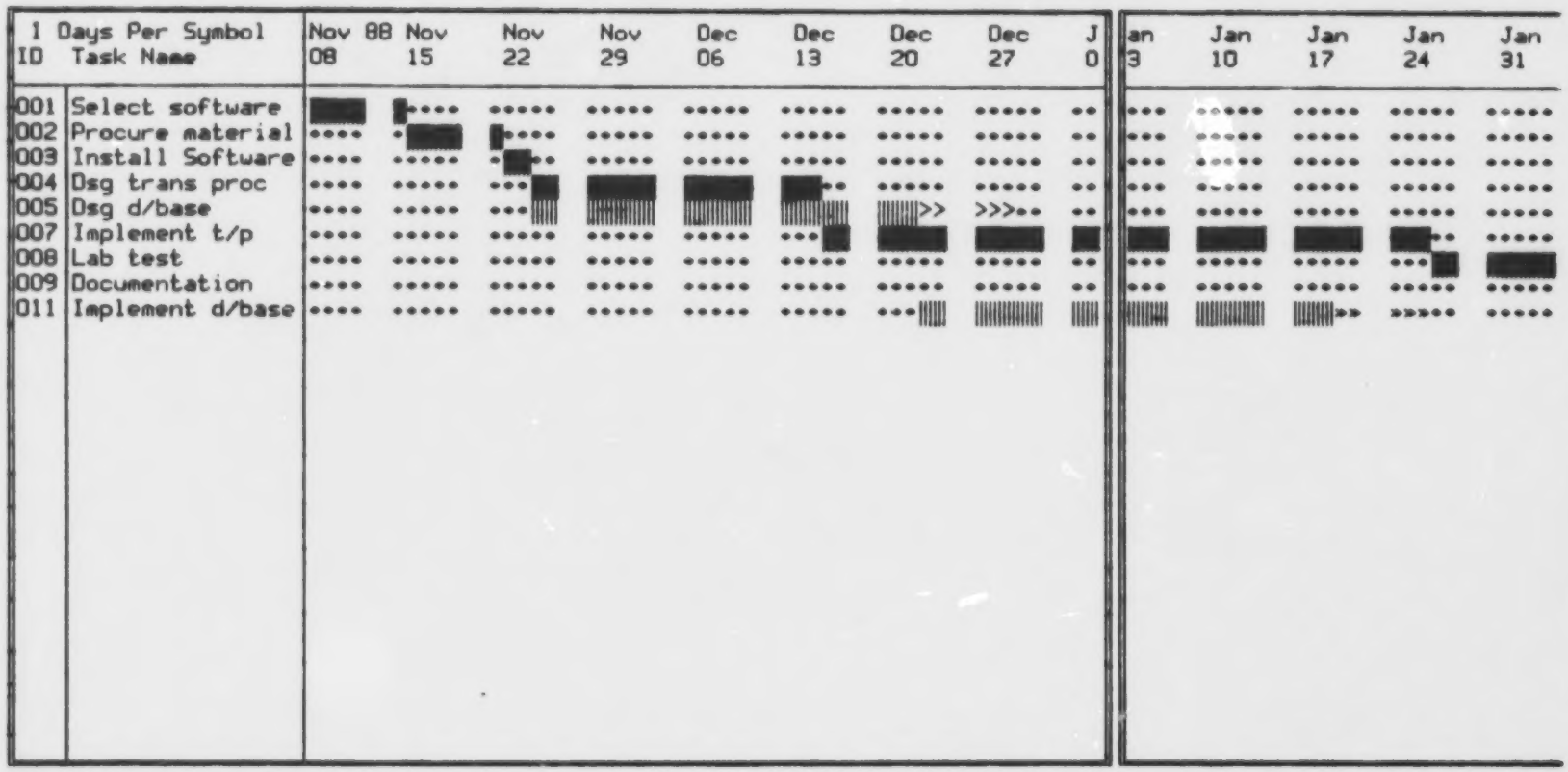
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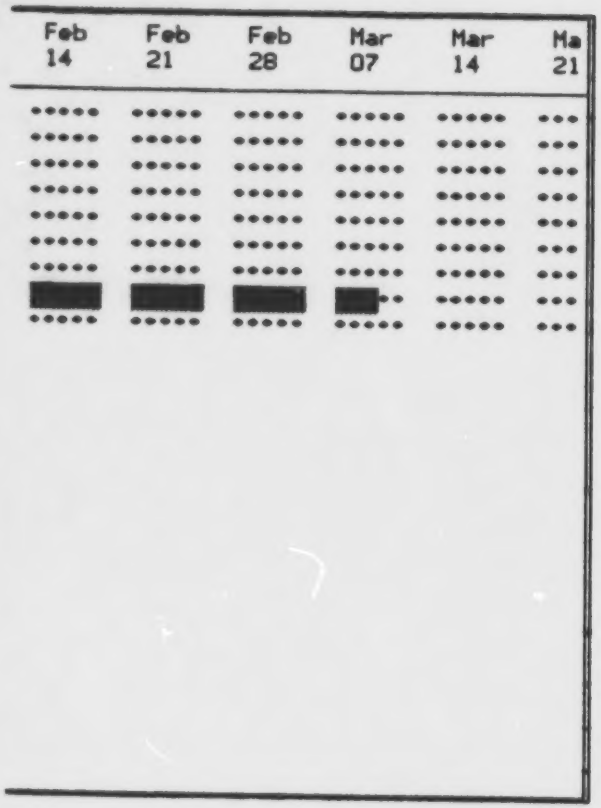
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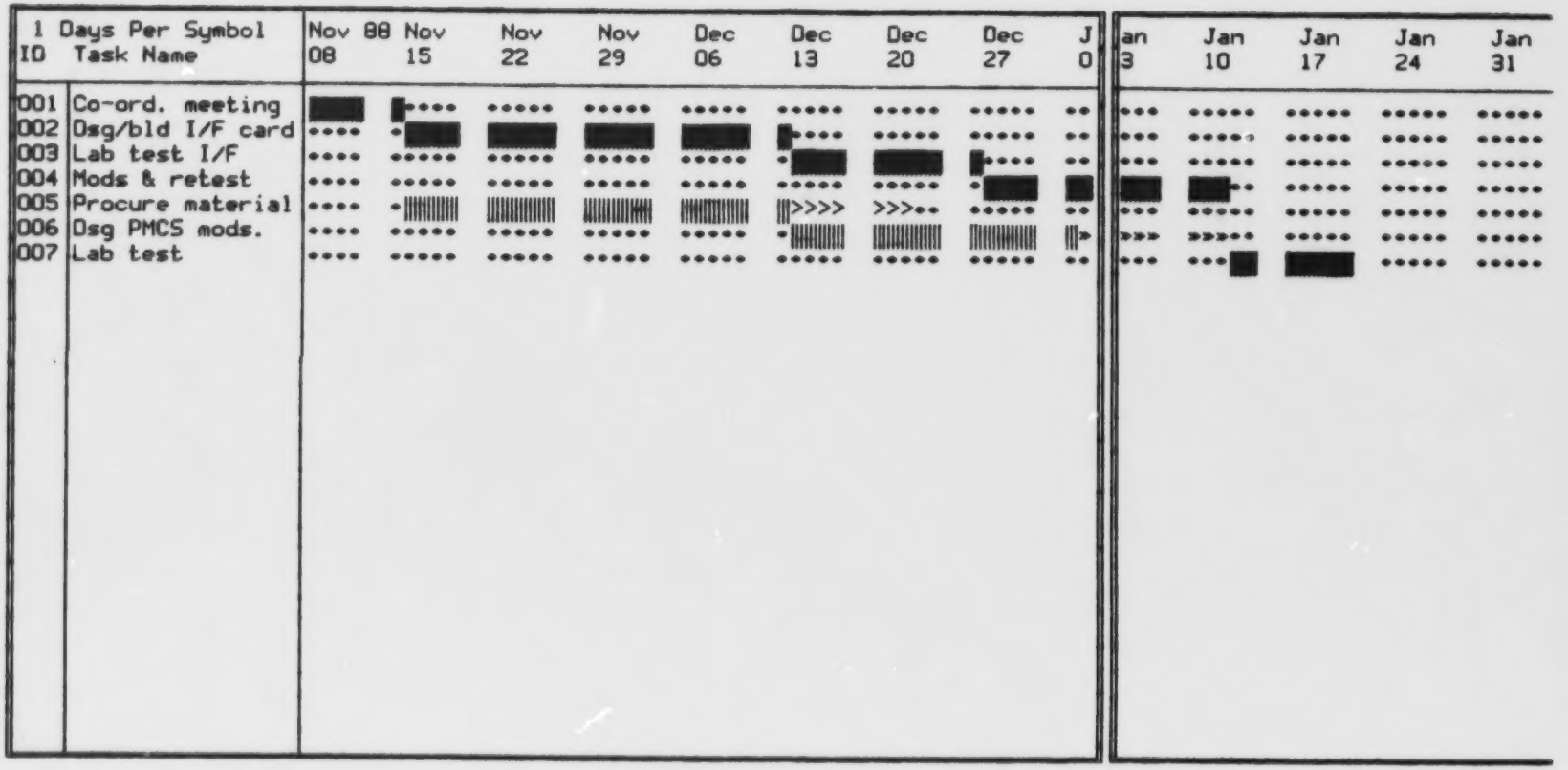
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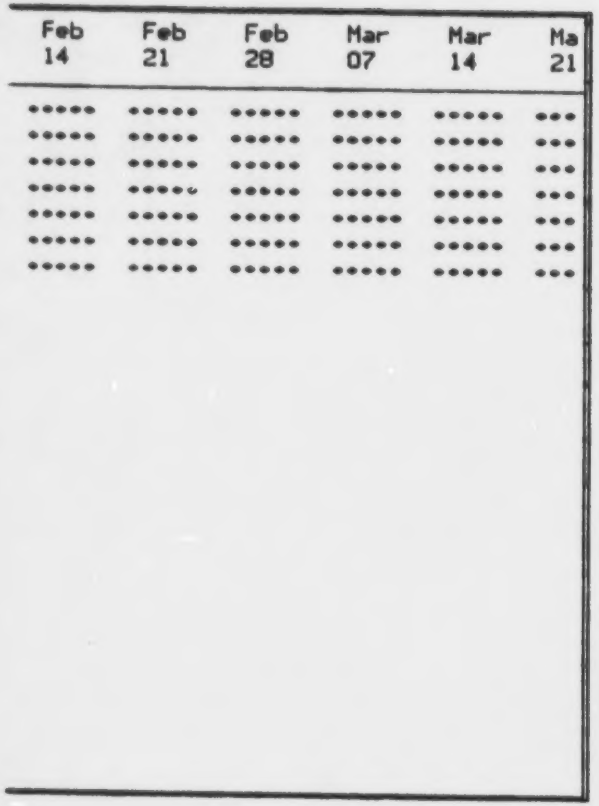
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APPENDIX X

CANMET RFP

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APPENDICES

"A" Statement of Work, Delivery Schedule and Deliverables
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ENCLOSURES

DSS 1031-1 - Contract Cost Principles
DSS 1035 - Supplemental General Conditions - Subletting
DSS 9224 - General Conditions - Research and Development
TEMP 1078 - Federal Contractor's Program for Employment Equity

DSS MAS 5201 S (4/88) 7530-21-836-8376

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1.0 STATEMENT OF WORK (See Appendix "A")

2.0 INTRODUCTION AND GENERAL INSTRUCTIONS

See the reverse side of page 1 for instructions and Conditions which form part of this Request For Proposal (RFP).

3.0 NON-COMPLIANCE WITH TERMS OF RFP

Failure to comply with the requirements of this Request for Proposal may result in your Proposal being declared non-responsive.

4.0 PROPOSAL PREPARATION INSTRUCTIONS

4.1 Submission of Proposal

You are invited to submit a proposal, in three (3) copies, to fulfill all the requirements of this Request for Proposal (RFP). When responding, your proposal is to be submitted to:

Bid Receiving Unit
Supply Administration
Department of Supply and Services Canada
Main Lobby, Room OA1
Place du Portage, Phase III
11 Laurier Street
Hull, Quebec, K1A 1C9
TELEX: 053-3703

Your attention is drawn to Appendix "B", "Contractor Selection, Anticipated Project Cost and Evaluation Criteria" against which proposals will be evaluated. Each proposal will be evaluated solely on its content.

Your proposal should be structured in four (4) parts, namely:

(a) Technical Proposal, Item 4.2
(b) Management Proposal, Item 4.3
(c) Price Proposal, Item 4.4
(d) Method of Payment Proposed, Item 4.5

4.2 Technical Proposal

Your technical proposal should be concise and should address, but not necessarily be limited to, the following points:

(a) State your approach and proposed methodology to meet the requirement, the degree of success expected, and any major difficulties that are anticipated. Provide sufficient detail to demonstrate your grasp of the requirement and your competence to meet it.

(b) State your request for any changes to the Statement of Work. Such changes shall be clearly identified and shall be priced separately as an option. However, your technical proposal must meet the requirements of the Statement of Work as specified therein.

(c) Identify the personnel who will be assigned to this requirement showing experience, education (including dates of any degrees) and qualifications. Identify level of effort by task for individual personnel.

(d) Outline the background and experience of your organization, particularly as it relates to this requirement.

(e) Identify any proprietary information which you propose to use in the program.

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4.3 Management Proposal

A comprehensive Management Plan shall be submitted as part of your proposal. This plan shall address, but not necessarily be limited to the following points:

(a) Specify the time schedule, manpower loading and the cash flow on the "Contract Plan and Report Form" attached as Appendix "F" to this RFP or an acceptable alternate format. Ensure individual Phases or Tasks are identified. Show delivery dates for all deliverable items. The Contract Plan and Report Form shall be part of the contract, be updated monthly and be submitted with each progress report. Receipt and acceptance of progress reports will be a condition for payment of progress claims.

(b) Specify how you propose to control the management of the program and identify the project manager who will be responsible for the overall control. Identify the system you will use to control costs and labour.

(c) Specify how you propose to control the management of subcontracts as applicable.

4.4 Price Proposal

The price proposal Summary Sheet (Appendix "C") or an acceptable alternate format is required to be submitted as part of your proposal. The price proposal should contain a detailed breakdown of the total quoted price. Provide a breakdown for individual Phases or major Tasks separately. The price proposal should address each of the following as applicable:

(a) Labour:

For each individual and/or labour category to be employed on the project, indicate the proposed time rate and the estimated time to be spent by each.

Support the labour rates proposed by providing details as follows:

$$\text{Labour rate} = \frac{\text{Annual Salary + Overhead of ( )\%}}{\text{Available Days or Hours Per Year}}$$

Do not include profit in the labour rates. Profit should be addressed separately [See Item (h)].

Although detailed support for the rates is not requested at this time, you should be prepared to provide same if requested.

(b) Equipment:

Indicate items required for the work, inclusive of applicable federal sales tax and custom duties, and which will be recoverable by the Crown upon completion of the project. Where possible, specify the manufacturer, model, supplier, price and the basis for the price.

(c) Leases:

Provide utilization and cost estimates for all equipment which would be leased from external sources specifically for use on this project. Similarly, identify equipment which you own which will be a direct rental charge to the contract.

(d) Materials, Supplies and Components:

Indicate general categories of materials, supplies and components of the sort likely to be used or consumed during the course of the work.

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(e) Subcontracts:

List individually any subcontracts proposed, describing the work to be performed and giving a cost breakdown; identify basis of selection.

(f) Travel and Living:

Provide a cost estimate for each trip, specifying travellers, purposes, destinations, duration of trips, modes of transportation, meals and accommodation. State what costing guidelines you will use for travel and living. When stating company guidelines attach a copy. In the absence of written company guidelines, recommended Travel and Living Guidelines are attached.

(g) Other Charges:

List any other charges which may be applicable, giving an estimated cost for each (e.g. long distance communications, reproduction, shipping, etc.).

(h) Profit or Fee:

State your proposed profit or fee, if any, and the basis on which it is applied or computed.

(i) Price Certification:

Please provide the certification(s) requested in Appendix "C", attached hereto.

(j) Sales Tax:

Various items in your cost proposal may be subject to federal sales tax and custom duties, and this charge must be included in the cost estimates where applicable.

(k) Price Negotiations:

If required, all price negotiations will be carried out in accordance with Contract Cost Principles DSS 1031-1 (copy attached).

4.5 Method of Payment

Although payment will normally be made in full following completion, delivery and acceptance of the work, progress payments will be considered if requested. Bidders should be aware that the method of payment requested will constitute a price evaluation criterion. For evaluation purposes, calculations will be made in accordance with the method as described in Appendix "D", attached hereto.

Unless stipulated otherwise in the price proposal section of this RFP, the following methods of payments are listed below in order of preference to the Crown:

a) Payment for milestones achieved, (milestone defined as a method of making a progress payment which relates to a measurable/defined item or work package for which a price can be assigned with a good probability that such assigned price will turn out to be within reasonable limits of predictive accuracy for the value of the work);

b) Payment for costs incurred (plus pro-rated fee or profit): i) at completion of specified milestones or ii) on a time basis;

c) Combination of a) and b) above.

The proposal shall clearly identify in detail the method of payment requested.

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Progress payments for costs incurred will be made not more frequently than once a month upon the following terms and conditions.

a) Progress claims shall be completed in full and shall include a progress/interim report of the work to the date of the claim, and submitted to the Minister on Form DSS 1111. The progress payment will be subject to the acceptance of the progress/interim report for the corresponding period of the claim for payment.

b) All the Certificates appearing on the said form are to be signed by or for the respective persons indicated thereon.

c) Progress payments will be made up to 90% of the claimed amounts approved by the Minister but in no event will cumulative payments exceed 90% of the contract value.

d) Each progress claim will show:

i) Expenditures plus pro-rated profit or fee or alternatively the value of milestones during the claim period by line item as detailed in the payment terms of any contract resulting from this proposal;
ii) Federal Sales Tax (if applicable);
iii) Holdback at 10%.

4.6 Employment Equity Federal Contractor's Program Certification

The requirements of the Federal Contractor's Program for Employment Equity may apply. A notice to this effect and instructions have been included in this bid solicitation package.

A statement of Employment Equity shall be submitted by the Proposer on Form TEMP 1078 (07-86) (if applicable).

4.7 Payment Provisions

Under any contract awarded as a result of this RFP, the following contract clauses may be applied depending on the Method of Payment negotiated:

1) For use in all Contracts providing for payment on completion:

(a) Payment by Her Majesty for the work shall be made within:

(i) thirty (30) days following the date on which all of the work has been delivered and all other work required to be performed by the contractor under the terms of the contract has been completed;

(ii) thirty (30) days following the date on which an invoice and substantiating documentation are received according to the terms of the contract;

whichever is later.

(b) If Her Majesty has any objection to the form of the invoice or the substantiating documentation, within (15) fifteen days of its receipt, Her Majesty shall notify the Contractor of the nature of the objection. "Form of the invoice" means an invoice which contains or is accompanied by such substantiating documentation as Her Majesty requires. Failure by Her Majesty to act within 15 days will only result in the date specified in paragraph 1 of the clause to apply for the sole purpose of calculating interest on overdue accounts.

2) For use in Contracts providing for progress payments:

Payment by Her Majesty to the Contractor for the work shall be made:

(a) in the case of a progress payment other than the final payment, within thirty (30) days following the date of receipt of a duly completed progress claim form DSS 1111;

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(b) in the case of a final payment, within thirty (30) days following the date of receipt of a duly completed final progress claim form DSS 1111, or within thirty (30) days following the date on which the work is completed, whichever date is the later;

(c) if Her Majesty has any objection to the form of the progress claim, within fifteen (15) days of its receipt, She shall notify the Contractor of the nature of the objection. "Form of the claim" means a claim which contains or is accompanied by such substantiating documentation as Her Majesty requires. Failure by Her Majesty to act within 15 days will only result in the date specified in sub-paragraph a) and b) of the clause to apply for the sole purpose of calculating interest on overdue accounts.

3) Interest on overdue accounts:

(a) (i) In this Article an amount is "due and payable" when it is due and payable by Her Majesty to the Contractor according to the terms of the contract.

(ii) For the purposes of this Article an amount is overdue when it is unpaid on the first day following the day upon which it is due and payable.

(iii) In this Article "date of payment" means date of the negotiable instrument drawn by the Receiver General for Canada and given for payment of an amount due and payable.

(iv) In this Article "Bank Rate" means the discount rate of interest set by the Bank of Canada.

(b) (i) Her Majesty is liable to pay, without demand from the Contractor, simple interest at the bank rate plus 1-1/4 per centum on any amount which is overdue from the date such amount became overdue until the day prior to the date of payment, inclusively; however, interest will not be payable nor paid unless the amount has been outstanding (unpaid) for more than 15 days following the due date. Interest will not be payable on overdue advance payments.

(ii) The Bank Rate shall be that prevailing at the opening of business on the date of payment.

(c) Interest shall only be paid when Her Majesty is responsible for the delay in paying the Contractor. In the event Her Majesty is not responsible for the delay in paying the Contractor, no interest shall be paid.

4.8 Corporate Name

The proposal shall contain a statement of the name and laws under which the company was legally incorporated and the percentage of Canadian ownership.

4.9 Notification of Mailing Through Canada Post

With reference to Section A3 on the reverse of page 1, bidders may wish to advise the DSS Science Branch Contracting Officer (designated herein) of timely mailing, prior to closing time and date.

4.10 Source List

Attached as Appendix "E" is the initial list of those receiving this Request for Proposal. It is not intended to update the distribution list to include additional names.

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5.0 ENQUIRIES/DSS SCIENCE BRANCH CONTRACTING OFFICER

All enquiries and other communications related to this Request for Proposal, throughout the solicitation period and until contract award, MUST be directed ONLY to the DSS Science Branch Officer Contracting named hereunder.

To ensure the equality of information among bidders, answers to enquiries which are relevant to the quality of proposals will be forwarded simultaneously to every bidder without revealing the sources of the enquiry. Such enquiries must be received at least seven (7) working days before the closing date.

Don Fraser
Science Procurement Officer
Science and Professional
Services Directorate
Science Branch
Department of Supply and Services
Place du Portage, Phase III, 11C1
11 Laurier Street
Hull, Quebec
K1A 0S5

TELEPHONE: (819/613) 997-7399
TELEX: 053-3703

6.0 TERMS AND CONDITIONS

6.1 Note Regarding Acceptance of Telex/Telegraphic Proposals

In order to avoid costly misunderstandings, the following information from the back of page 1 is repeated:

"Proposals submitted by Telegraphic means are acceptable provided they are received prior to the time specified for closing of proposals and contain the proposal reference number and closing date. Telegraphic proposals will constitute your formal proposal. Such proposals must be comprehensive and in sufficient detail so as to permit complete evaluation in accordance with the criteria set out herein. The Minister may consider entering into contract without negotiation on the basis of such telegraphic proposal."

6.2 Amendment to Terms and Conditions on back of Page 1

Under B. CONDITIONS, at line 2, delete "General Conditions for Contract, Short Form DSS-MAS 9329" and substitute the following therefor:

(a) General Conditions DSS 1035 (Subletting); and
(b) General Conditions Research and Development DSS 9224, as amended hereunder:

i) Inspection: Article 7 of the Terms and Conditions DSS 9224 is hereby supplemented by adding the following subsection:

(5) The Contractor shall not stop or suspend work pending the settlement or determination of any differences arising under the contract, unless so instructed by the Minister.

ii) Subcontracts: Article 11 of the Terms and Conditions DSS 9224 is hereby supplemented by adding the following sentence to subsection (1):

For work requiring consent of the Crown, should the Contractor propose to solicit bids from other than Canadian sources, he shall obtain the consent, in writing, of the Minister prior to solicitation.

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iii) Termination, Suspension, Change:

Paragraph (b) of subsection 2 of Article 21 of Terms and Conditions 9224, is deleted in its entirety and the following is substituted therefor:

(b) the Work or any portion of the Work is terminated, the Contractor shall be paid for all finished deliverables, delivered and accepted and for all materials or work-in-process delivered and acceptable to Her Majesty, the Cost to the Contractor in accordance with the terms of the contract plus the proportional part of any fee applicable thereto. The Contractor shall also be entitled to be reimbursed its costs which are incidental to the cancellation of obligations incurred by the Contractor pursuant to the termination notice, the cost of preparing the necessary accounts and statements with respect to the Work performed to the effective date of such termination and commitments made by the Contractor with respect to the terminated portion of the Work, wages which the Contractor is obliged under any laws or regulations for the time being in force, to pay employees whose services are no longer required by reason of such termination, the costs of and incidental to the taking of any inventory of materials, components, work-in-process and finished work on hand at the effective date of the termination and other costs and expenses of and incidental to the termination in whole or in part, of operations under the Contract; provided always that payment and reimbursement under that provisions of the sub-section shall be made only to the extent that is established to the satisfaction of the Minister that the said costs and expenses were actually incurred by the Contractor and that the same are reasonable and are properly attributable to the termination of the Work or the part thereof so terminated.

(c) The aggregate of the price paid to date and the amounts payable pursuant to this Article, shall not in any event exceed the total Contract Price.

(d) The Contractor shall have no claim for damages, compensation, loss of profit, allowance or otherwise by reason of or directly or indirectly arising out of any action taken, or notice given by the Minister under or pursuant to the provisions of this Article except as and to the extent in this Article expressly provided."

6.3 RIGHTS OF THE CROWN

The Crown reserves the right to:

(a) reject any or all proposals received in response to this RFP;

(b) enter into negotiations with one or more bidders on any or all aspects of its proposal;

(c) accept any proposal in whole or in part;

(d) cancel and/or re-issue this requirement at any time; and

(e) award one or more contracts; and

(f) verify any or all information provided by the bidder with respect to this requirement.

6.4 TIME EXTENSION TO CLOSING DATE

A request for a time extension to the closing date will be considered provided it is received in writing by the DSS Science Branch Officer named herein at least seven (7) working days before closing date shown herein.

The request, if granted, will be communicated to all invited bidders at least three (3) working days before closing, by telex showing the revised closing date.

The request, if rejected, will be directed to the originator, also by telex, at least three (3) working days before closing.

6.5 CAPABILITY SURVEY

If an offer submitted in response to this solicitation is favourably considered, a survey team may contact your facility to determine your technical and financial ability to perform. If so, current financial statements and other pertinent data should be available at that time, if not already on file with DSS.

6.6 PROPOSAL COST

No payment will be made for costs incurred in the preparation and submission of a proposal in response to this RFP.

No cost incurred before receipt of a signed contract or specified written authorization from the DSS Science Branch Contracting Officer can be charged to the proposed contract.

6.7 ADDITIONAL TERMS AND CONDITIONS APPLICABLE TO CONTRACTS

6.7.1. Inspection and Acceptance

The work performed under any contract resulting from this RFP shall be subject to inspection and acceptance by the Scientific Authority to be designated in the contract.

6.7.2 Conflict of Interest

It is a term of any contract resulting from this RFP that:

(1) no former public office holder who is not in compliance with the post-employment provisions of the Conflict of Interest and Post-Employment Code for Public Office Holders shall derive a direct benefit from this contract; and

(2) during the term of the contract any persons engaged in the course of carrying out this contract shall conduct themselves in compliance with the principles of the Conflict of Interest and Post-Employment Code for Public Office Holders. Should an interest be acquired during the life of the contract that would cause a conflict of interest or seem to cause a departure from the principles, the Contractor shall declare it immediately to the departmental representative.

6.7.3 South African Condition

Subject to the following paragraph, the Contractor represents and warrants that, to its knowledge, the goods or services to be provided pursuant to this contract are neither of South African origin nor from majority-owned (51 percent of the voting rights) South African companies located outside of South Africa.

In the event that such goods or services are to be supplied as part of this contract, the Contractor must identify these in writing to the Minister as part of its response.

A proposal or tender may be rejected if the contract would result in the supply to Her Majesty of such goods or services.

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APPENDIX "A"

STATEMENT OF WORK

In the following statement of work the integrated system is referred to as the "system". The actual details of the proposed system are the responsibility of the contractor and must be contained within the bid, however, the following brief component descriptions are included for guidance:

1. Computer Simulation Program

This program is intended for short to medium term production scheduling and should continually accept and process on-site generated data (i.e. the program will use actual mine site data to predict equipment performances).

This program is expected to be developed in several modules that may be used independently. The program will accept real time data generated and collected by the mine site equipment information system and drive the dispatching program.

2. Dispatching Program

This program should dispatch trucks in real time in accordance with mine site policies.

It is proposed that the dispatching system be set up at the beginning of each shift, monitor truck-shoval performance in relation to this basic set-up, and reassign in keeping with specified mine site requirements. This system must allow for user interaction at anytime, and provide trend information as specified by the user.

3. Equipment Information System

This system, with appropriate software, is expected to monitor relevant operating, maintenance and equipment performance data and feed these data for further processing in simulation and dispatching programs. Types of data covered by this information system are expected to be defined by the producing mining companies.

4. Data Transfer System

A radio based two way communications system that can send monitored information to a central computer for processing, and relay dispatch decisions as well as provide voice communication is an example of such a data transmission system.

The system should also provide temporary on-line storage of data for "on-demand" transmission and further processing.

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5. Mobile Equipment Location Devices

This hardware and program software will locate and continuously update equipment location using satelite or terrestrial based facilities.

This automatic vehicle location system is defined as an assembly of technologies and equipment that permits centralized and automatic detection and display of the position and movement of vehicles through an area. The results of this system component will be integrated into the simulation program that drives the dispatching module.

Other uses of the vehicle location system may be defined by the user.

In essence the computer simulation program will take equipment information and location systems outputs relayed by the data transmission system, conduct simulations, apply the logic of the dispatch program and inform equipment operators of dispatch decisions.

The central computing facility may also subject the collected data to other analyses to provide operating, management and maintenance information but those subjects are beyond the scope of this request for proposals.

Using existing, purchased and/or developed (either in-house or by subcontract) equipment the contractor will in consultation with the Scientific Authority:

1. Integrate some or all of the five components (computer simulation program, dispatching, equipment information, data transmission and equipment location).

2. Install, commission, validate and operate the system in a producing mine for a period of at least 12 months.

3. Evaluate and assess the performance of the system. This will include as a minimum:

   a) the reliability, repeatability, accuracy, and utility of the various system components and outputs.
   b) a comparision of the performance, productivity and operating efficiency changes resulting from the introduction of the system.
   c) a cost-benefit study of the site-specific application of the system,
   d) a discussion of the problems and successes associated with the work, and
   e) recommendations for improvements to the system.

4. It is recognized that such a demonstration project contains an element of risk. Should the selected system prove unacceptable to the contractor at any time, the Scientific Authority and the contractor may agree to premature cancellation of the trial for reasonable grounds.

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DELIVERY SCHEDULE

The work on this project is expected to be delivered by March 31, 1990.

DELIVERABLE ITEMS

Monthly Interim Reports

Monthly interim reports in letter format are to be submitted in five copies to the Scientific Authority. These interim reports must define the system performance, must include data collected by the system and must compare that data with the daily log of movement of monitoried trucks. Each interim report must be accepted in writing by the Scientific Authority.

Regular reference should be made to the Statement of Work, the project schedule and the cost estimate in the proposal.

Final Report

A final report shall be submitted in 20 copies for the approval of the Scientific Authority. This report must be comprehensive dealing with all facets of the work and must include sufficient drawings, sketches, photographs and a discussion of the problems and successess associated with the work to facilitate a full and accurate evaluation of the work by the Scientific Authority. The report will be prepared in accordance with good engineering practice and will include as a minimum the following format:

(a) executive summary (in both english and french)
(b) introduction
(c) discussion
(d) conclusions and supporting
(e) tables and graphs

The final report shall be subject to inspection by the Scientific Authority prior to acceptance and should the report not be in accord with this contract, the Scientific Authority shall have the right to reject it or require its corrections. This demonstration project includes the acquisition of hardware and software. That hardware is not a deliverable; disposal or retention of the hardware is the responsibility of the Contractor.

Seminar

After submission and acceptance of the final report, the Contractor shall prepare a verbal presentation outlining the problems and successes associated with the work and present this material in a one day debriefing session to CANMET representatives and interested outside parties. The time and location (usually Edmonton) of the presentation will be at the discretion of the Scientific Authority who may, also, decide that the work does not warrant presentation. Costs associated with the debriefing in Edmonton, Alberta are expected to be included in the bid.

Canada

APPENDIX "B"

EVALUATION CRITERIA, CONTRACTOR SELECTION AND ANTICIPATED PROJECT COST

EVALUATION CRITERIA

Your technical and management proposal will be evaluated and scored in accordance with the following evaluation criteria. It is suggested you address these criteria in sufficient depth in your proposal.

Technical Proposal: (50 points, minimum 37.5)

a) understanding of scope and objectives

b) proposed work feasibility, approach and methodology

c) economic impact potential

d) recognition of problems and solutions proposed

e) personnel and company

- i) relevant experience, qualifications
- ii) competence proven by similar and/or related work
- iii) team organization planned

e) adequacy of level of effort

Management Proposal: (50 points, minimum 37.5)

a) work plan and schedule

b) project manager

- i) relevant experience, qualifications
- ii) his/her position within organization

c) demonstration of availability of team members and backup capability

TOTAL: ___/100 points

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DATE DE L'EXPORTATION
IMPORT DATE
DATE DE L'IMPORTATION
EXPORTER CODE
CODE DE L'EXPORTATEUR
IMPORTER CODE
CODE DE L'IMPORTATEUR
COMMENT SUPPORT LIST
LISTE DE MATERIEL ACCESSOIRE
DSS FILE NO. / N° DE REFERENCE DSS
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APPENDIX "B"

CONTRACTOR SELECTION

(a) Subject to the Evaluation Criteria above, the successful bidders will be chosen in descending order from those firms obtaining the highest technical scores at costs not to exceed $200,000 Crown funds per component. Bidders who wish to offer a proposal involving more than one component may do so providing the bid price does not exceed an average of $200,000 Crown funds per component. In all cases, the Crown share will constitute no more than 1/3 of the total project cost. Only those proposals achieving a score of 70% or better in each of the items of the evaluation criteria will be considered for contract award. Where two or more identical scores are assigned, consideration of the Method of Payment proposed (4.5), will be used in making the final selection. Where two or more acceptable bids are received, socio-economic criteria may also be used.

(b) In accordance with Treasury Board Policy on contracting-out Science and Technology, the highest priority shall be accorded to Canadian Industrial performers. This in no way precludes the use of other performers in the private sector, including universities and non-profit organizations as subcontractors on any project. In cases where a Canadian industrial performer proposes to subcontract a substantial majority of the work to a university or non-profit organization, the proposal must fully address the degree of technology transfer to be accomplished and how such acquisition of capabilities will enhance the future operations of the prime contractor. Where the degree of technology transfer is not adequately addressed or cannot be established, such proposal may not received further consideration until it can be determined that there are no acceptable proposals from Canadian industrial sources.

(c) The Crown reserves the right to award contracts for follow-on work, if any, to the successful bidder for this requirement.

CONDITION OF CONTRACT AWARD

Notwithstanding the Contractor selection clause above, bidders are reminded that the Crown may negotiate the Basis of Payment with the selected bidder prior to contract award (see signature box, page 1).

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APPENDIX "C"

PRICE PROPOSAL SUMMARY SHEET AND PRICE CERTIFICATIONS

PRICE PROPOSAL SUMMARY

1. LABOUR: at firm hourly rates inclusive of overhead, exclusive of profit, in accordance with the following:

Category/Personnel	Estimated Hours	Firm Hourly Rate
a)		
b)		
c)		
d)		
e)		
f)		
g)		
h)		

TOTAL ESTIMATED COST OF LABOUR: $_____

2. EQUIPMENT: at laid down cost without mark-up inclusive of F.S.T. and Customs Duty

Description	Price
a)	
b)	
c)	
d)	
e)	
f)	

TOTAL ESTIMATED COST OF EQUIPMENT: $_____

3. RENTALS: at laid down cost without mark-up

a) External Sources:

Description	Price

b) Contractor Owned:

Description	Price

TOTAL ESTIMATED COST OF RENTALS: $_____

4. MATERIALS, SUPPLIES, INSTRUMENTATION, COMPONENTS: at laid down cost without mark-up

Description	Price

TOTAL ESTIMATED COST OF MATERIALS, SUPPLIES, ETC.: $_____

.../2

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5. SUBCONTRACTS: at laid down cost without mark-up, subject to the provisions of Supplemental General Conditions DSS 1035 (Subletting)

   Support in the same detail as required for the prime contractor is required for proposed subcontracts in excess of $10,000.00, in order to obtain consent of the Crown for subcontracts. The estimated price for subcontracts includes all direct charges and travel and living which would be to the account of the subcontractor.

   Provide details on a separate sheet.

   TOTAL ESTIMATED COST OF SUBCONTRACTS: $_____

6. TRAVEL AND LIVING: at actual cost not to exceed Treasury Board Guidelines (see Appendix "G") if no alternate proposed by contractor.

   Provide details for travel on a separate sheet.

   TOTAL ESTIMATED COST OF TRAVEL AND LIVING: $_____

7. OTHER CHARGES: at laid down cost without mark-up

Description	Price

   TOTAL ESTIMATED COST OF OTHER CHARGES: $_____

8. PROFIT AND FEE:

   Basis of Calculation:

   TOTAL ESTIMATED COST OF PROFIT AND FEE: $_____

9. DEBRIEFING SESSION:

   Provide details on a separate sheet

   TOTAL ESTIMATED COST OF DEBRIEFING SESSION: $_____

   TOTAL ESTIMATED COST OF PRICE PROPOSAL: $_____

CONDITIONS OF PRICE PROPOSAL SUBMISSION

1. It is a requirement of this Request For Proposal that a breakdown as stated above or an acceptable alternate format be provided as part of your Price Proposal.

2. A detailed work breakdown plan is required for each major task which indicates the assignment of team members to each, their individual level of effort by task, direct charges applicable to each task and the total estimated cost of each task. This should be prepared in conjunction with the requirement in the Management Proposal for a breakdown of manpower loading by task and is an extension of that requirement to include pricing.

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PRICE/RATE CERTIFICATION

You are requested to provide one (1) of the following certifications as applicable, in your price proposal.

a) **For a Firm Price Bid:**

"We hereby certify that the price quoted is based on costs computed in accordance with Contract Cost Principles DSS 1031-1 a copy of which we acknowledge to have received, and that the said price contains and estimated profit of $_____".

b) **For a Bid on a Cost Reimbursable Basis, using firm hourly or daily labour rates inclusive of overhead, the labour rates must be quoted exclusive of profit [profit will be considered as a separate item - see Items 4.4 (a)]:**

"We hereby certify that the labour rates quoted are based on costs computed in accordance with Contract Cost Principles DSS 1031-1, a copy of which we acknowledge to have received, and that the said labour rates contain an estimated profit of 0%."

c) **For a Bid on a Cost Reimbursable Basis, using a firm multiplier or formula, inclusive of overhead, (instead of firm time rates), the labour rates must be quoted exclusive of profit [profit will be considered as a separate item - see Item 4.4 (a)]:**

"We hereby certify that the firm multiplier quoted to calculate labour is based on costs computed in accordance with Contract Cost Principles DSS 1031-1, a copy of which we acknowledge to have received, and that the said firm multiplier quoted contains an estimated profit of 0%".

Canada

EXAMPLE OF COST OF FINANCING CALCULATION: QUARTERLY PROGRESS PAYMENTS METHOD

	1 Jan. 1, 83	2 Apr. 1, 83	3 July 1, 83	4 Oct. 1, 83	5 Jan. 1, 84	6 Apr. 1, 84	7 July 1, 84	8 Oct. 1, 84	9 Total
L. 1 Progress Payments	$100,000	$200,000	$200,000	$200,000	$200,000	$ 200,000	$ 200,000	$ 100,000	
L. 2 Cumulative Payments	$100,000	$300,000	$500,000	$700,000	$900,000	$1,100,000	$1,300,000	$1,400,000	$1,400,000
L. 3 Interest @ 12% pa (L.2 COL. $\frac{1 \times 12}{4} \times \frac{1}{100}$		$ 3,000	$ 9,000	$ 15,000	$ 21,000				
L. 4 1st yr interest compounded (ADD L.3, Col. 2 – 5)					$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000
L. 5 Cumulative Payment + Interest Compounded (L.2 + L.4)					$948,000	$1,148,000	$1,348,000	$1,448,000	
L. 6 Contract Value of Deliveries							($ 700,000)	($ 700,000)	
L. 7 Cumulative Value of Deliveries (L.6, Add Col. 7 + 8)							($ 700,000)	($1,400,000)	($1,400,000)
L. 8 Net Financing 2nd yr. (L.5 – L.7)					$948,000	$1,148,000	$ 648,000	$ 48,000	
L. 9 Interest on 2nd yr. Net Financing (L.8, Col. $\frac{5 \times 12}{4} \times \frac{1}{100}$						$ 28,440	$ 34,440	$ 19,440	$ 82,320
L. 10 Total Financing Cost $ (L.4 + L.9)									$ 130,320

NOTES

(1) The interest rate to be applied to the value of net financing is the chartered bank prime lending rate as advised periodically by the Comptroller, S.A.

(2) Interest is to be calculated periodically (quarterly in the above example) and compounded annually as illustrated.

(3) Calculation of financing cost for bid evaluation purposes is mandatory on competitive procurements utilizing the RFP method of bid solicitation. Such calculation may be waived when all responsive bidders have requested the identical method and pattern of financing (e.g. progress payments on cost incurred basis, with virtually identical payout schedules).

(4) For applicable procurements, the total financing cost (L.10 in the above example) would be added to the bid price to derive the total price for purposes of initial proposal evaluation. In the above example, if the bid price was $1,555,555 for 90% progress payments amounting to $1,400,000, the relevant total price will be $1,555,555 + $130,320 or $1,685,875.

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APPENDIX "E"

SOURCE LIST

The following is the initial list of those receiving this Request for Proposal. Proposals from others will be equally considered providing all terms and conditions set out herein are met. It is not intended to update the distribution to include additional names.

Crowsnest Resources (Line Creek Mine)
P.O. Box 2003
Sparwood, B.C.
V0B 2G0
Attn: Mr. D. Riva

Quintette Coal Ltd.
P.O. Box 1500
Tumbler Ridge, B.C.
V0C 2W0
Attn: Mr. J.H. Chamberlain

Fording Coal Limited
P.O. Box 100
Elkford, B.C.
V0B 1H0
Attn: Mr. J. Gray

Manalta Coal Ltd.
Gregg River Resources
Bag Service 5000
Hinton, Alberta
T0E 1B0
Attn: Mr. J. Chalmers

Coal Mining Research
One Oil Patch Drive
P.O. Bag 1400
Devon, Alberta
T0C 1E0
Attn: Mr. R.G. Chopiuk

Westar Engineering
600, 1130 West Pender Street
Vancouver, B.C.
V6E 2R6
Attn: Mr. Larry W. Hick

Norwest Resource Consultants Ltd.
400 - 205 - 9th Avenue S.E.
Calgary, Alberta
T2G 0R3
Attn: Mr. K.J. Hefferman

MacLaren Plansearch Corp.
Suite 1100
1140 West Pender Street
Vancouver, B.C.
V6E 4G1
Attn: Dr. J. Foster

Sandwell Swan Wooster Inc.
Suite 700
1190 Hornby Street
Vancouver, B.C.
V6Z 2H6
Attn: Mr. C.W. McLachlan

Byron Creek Collieries Limited
P.O. Box 270
Blairmore, Alberta
T0K 0E0
Attn: L. Hannan

Westar Mining Ltd.
Balmer Operations
P.O. Box 2000
Sparwood, B.C.
V0B 2G9
Attn: Mr. C. Van Eendenburg

Westar Mining
Greenhills Operations
P.O. Box 4000
Elkford, B.C.
V0B 1H0
Attn: Mr. D. Parsons

TransAlta Utilities Corp.
P.O. Box 1900
110-12th Avenue
Calgary, Alberta
T2P 2M1
Attn: Mr. D. Bacon

Highland Valley
Highland Valley Copper
P.O. Box 1500
Logan Lake, B.C.
V0K 1W0
Attn: Mr. A. MacPhail

Monenco Consultants Ltd.
400 Monenco Place
801 - 6th Avenue S.W.
Calgary, Alberta
T2P 3W3
Attn: Mr. I. Muirhead

Geomin Computer Services
408 Kapilano 100
West Vancouver, B.C.
V7T 1A2
Attn: Mr. S. Houlding

MacLaren Plansearch Ltd.
701 Purdy's Wharf Tower
1959 Upper Water Street
Halifax, Nova Scotia
B3J 3N2
Attn: Mr. S. Skey

T.E. Computing Inc.
5702-48 Avenue
Box 39
Beaumont, Alberta
T0C 0H0
Attn: S. Thornton

Phillip Barratt Kaiser Eng
200-2150 W. Broadway
Vancouver, B.C.
V6K 4L9

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Luscar Ltd.
Coal Valley Mine
P.O. Box 5000
Edson, Alberta
Attn: Mr. B. Latimer

Luscar Ltd.
Cardinal River
Bag Service 2570
Hinton, Alberta
Attn: R. Cains

Luscar Ltd.
Paintearth Mine
P.O. Box 730
Forestburg, Alberta
T0B 1N0
Attn: Mr. K. Haddock

Luscar Ltd.
Boundary Dam Mine
P.O. Box 908
Estevan, Saskatchewan
S4A 2A7
Attn: Mr. P. Bowman

Brenda Mines Ltd.
P.O. Box 420
Peachland, B.C.
V0H 1X0
Attn: Mr. J. Currie

Afton Operating Corporation
P.O. Box 937
Kamloops, B.C.
V2C 5N4

McIntyre Mines Ltd.
P.O. Box 2000
Grande Cache, Alberta
T0E 0Y0

Curragh Resources
P.O. Box 1000
Faro, Yukon
Y0B 1K0
Attn: Mr. M. Pelley

Teck Corporation
Bullmoose Mines
P.O. Box 500
Tumbler Ridge, B.C.
Attn: Mike Lipkewich

Mining Resources Eng. Ltd.
8 Princess Street
Kingston, Ontario
K7L 1A2
Attn: P. Calder

La Compagnie Miniere Quebec Cartier
Fermont, Quebec
G0G 1J0
Attn: Mr. Y. Montembeaut

Mr. Bos
Modern Graphics
#2, 3704 6th Street N.E.
Calgary, Alberta
T2E 6K5

AVL Ltd.
206 - 7th Avenue S.W.
Suite 507
Calgary, Alberta
T2P 0W7
Attn: J.T. Lockhart

Manalta Coal Ltd.
Utility Mine
Estevan, Saskatchewan
Attn: Mr. B. Weymark

Suncor Inc.
P.O. Box 4001
Fort McMurray, Alberta
T9H 3E3
Attn: Mr. E. Pacholko

Syncrude Canada
P.O. Box 4009
Fort McMurray, Alberta
T9H 3L1
Attn: Mr. W. McKee

Canada

FOR INFORMATION COPIES ONLY

[SEE CONTRACTOR SELECTION (b) IN APPENDIX "B"]

Mr. C.N. Baronet
Vice-Président
Centre de Recherche Industrielle
du Québec
C.P. 2000, Station Youville
Montréal, Québec
H2P 2X1

Mr. T. B. Nickerson
President
Nova Scotia Research Foundation
Corporation
100 Fenwick Street, P.O. Box 790
Dartmouth, N.S.
B2Y 3Z7

Dr. D.W. Duncan
Vice-President, Operations
B.C. Research
3650 Wesbrook Mall
Vancouver, B.C.
V6S 2L2

Mr. R. Maithel
Vice-President, Business Development
Saskatchewan Research Council
15 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 2X8

Canadian Energy Research Institute
3512-33rd Street N.W.
Calgary, Alberta
T2L 2A6

Dr. Roy Boorman
Executive Director
The New Brunswick Research
and Productivity Council
P.O. Box 6000
Fredericton, N.B.
E3B 5H1

Dr. D. Henderson
Vice-President Operations
Business Planning & Coordination
Ontario Research Foundation
Sheridan Park Research Community
Mississauga, Ontario
L5K 1B3

Mr. R.L. Morris
Marketing
Resource Technology Dept.
Alberta Research Council
P.O. Box 8330
Postal Station F
Edmonton, Alberta
T6H 5X2

Mr. .P. Haberman
Director
Industrial Technology Centre
Manitoba Research Council
1329 Niakwa Road East
Winnipeg, Manitoba
R2J 3T4

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Canada

CONTRACT PLAN AND REPORT FORM

Instructions to Contractor

This form serves a dual purpose; the first is for planning and estimating the work, and the second is for reporting actual progress against the plan during contract execution.

PROPOSED PLAN

Your work and cost plan must be prepared on this "Contract Plan and Report Form" DSS-MAS 9143-3 and must be submitted as part of your proposal. The plan shall demonstrate how you propose to execute the contract by subdividing the work into tasks and providing for each task an estimate of the cost and a schedule for completion. An example of a completed form is attached, (page I).

Use additional pages if the number of tasks exceed 15, or if the contract duration will exceed 12 months. For high value contracts in excess of $1M you are required to subdivide the work into major tasks which in turn are to be subdivided into minor tasks, e.g. a system is divided into subsystems which in turn are divided into subtasks, such as subsystem components.

You will be required to revise your plan to reflect the results of the contract negotiation. The revised plan will form part of contract.

REPORTING PROGRESS

Following contract award, monthly progress reports which record actual start dates and projected completion dates by task, actual cost by task, actual cost by month, Estimate to Complete (E.T.C.) by task and E.T.C. by month are to be prepared and submitted in accordance with the attached example, (page II), unless otherwise noted in the contract.

NOTE: The contract file number, serial number and the actual months duration are to be entered in the appropriate blocks of the first and subsequent reports. The report period is to be indicated by drawing a solid vertical line at the end of the applicable month. Your progress report must be completed to the satisfaction of the Science Procurement Manager before progress claims will be processed for payment.

The following points concerning the attached example should be noted:

1) Reports actual progress to the end of August.

2) Actuals by month are recorded on the bottom line at the left of the date line and Estimate to Complete by month to the right of the date line.

3) MECHANICAL SUBSYSTEM Material Procurement started one month late, is projected to be completed on time, has cost $4M and the Estimate to Complete is $1M. Total subtask is expected to cost $5M.

4) MECHANICAL SUBSYSTEM Assembly is expected to start one month late and to be completed one month late. The expected late completions are to be highlighted using broken lines.

5) ELECTRICAL SUBSYSTEM Assembly started one month early and is expected to be completed one month early.

6) DISPLAY CONTROL SUBSYSTEM Procurement is 50% complete in terms of cost. The estimated completion date has slipped 2 months.

7) SYSTEM INTEGRATION AND SYSTEM TEST are both expected to start one month late reflecting the one month delay in MECHANICAL SUBSYSTEM Fabrication and Assembly.

8) As of the end of August, the total contract cost is expected to be $26M ($12.7M Actual plus $13.3M E.T.C.) or to equal the planned cost of $26M. The contract is expected to be completed one month later than planned.

FORMULE DE PROJET DE CONTRAT ET RAPPORT

Instructions aux entrepreneurs

Cette formule a un double but; elle sert premièrement à planifier et estimer le travail, et deuxièmement, à vérifier, tout au long de l'exécution du contrat, si les travaux se déroulent selon le plan.

PLAN PROPOSÉ

Les plans concernant les travaux et les coûts prévus doivent être établis sur la "Formule de projet de contrat et de rapport" DSS-MAS 9143-3 et doivent être présentés comme faisant partie de votre proposition. Le plan doit faire état de la façon dont vous prévoyez mettre le contrat à exécution en divisant le travail en tâches et en donnant, pour chaque tâche, une estimation du coût et un calendrier d'exécution. Ci-joint à la page I un exemple de formule remplie.

Utilisez des pages additionnelles si le nombre de tâches dépasse 15 ou si la durée du contrat est de plus de douze mois. Pour les gros contrats d'une valeur supérieure à $1M, divisez le travail à accomplir en tâches principales que vous subdiviserez par la suite en tâches secondaires. Pensez, par exemple, à un système divisé en sous-systèmes, qui, à leur tour, sont subdivisés en sous-tâches, comme des composants du sous-système.

Vous devrez réviser votre plan pour tenir compte des résultats des négociations; le plan révisé fera partie du contrat.

RAPPORT DE SITUATION

Lorsqu'un contrat est adjugé, il faut remplir un rapport de situation mensuel indiquant la date à laquelle chaque tâche a été entreprise, ainsi que la date prévue d'achèvement de chaque tâche, la somme dépensée tous les mois pour chaque tâche et le coût prévu d'achèvement par tâche et par mois et présenter ce rapport de la façon indiquée à la page II ci-jointe, à moins qu'il n'en soit indiqué autrement dans le contrat.

NOTA: Le numéro de dossier du contrat, le numéro de série et la durée actuelle en mois doivent être inscrits dans les cases correspondantes du premier rapport et des rapports subséquents. La fin de la période visée par le rapport doit être indiquée au moyen d'un trait vertical plein après le mois en question. Le rapport de situation doit être jugé satisfaisant par le directeur de l'approvisionnement scientifique avant que les demandes d'acompte ne soient traitées.

Soulignons les points suivants en ce qui concerne l'exemple annexé:

1) Les progrès, y compris ceux accomplis à la toute fin du mois d'août, figurent sur le rapport.

2) Les coûts réels, par mois, figurent en bas, à gauche du trait vertical plein indiquant la fin de la période visée par le rapport; le coût prévu pour l'exécution complète, en bas, à droite du trait vertical.

3) Ainsi, on voit que l'achat de matériel pour le sous-système mécanique a commencé un mois en retard, qu'on prévoit qu'il sera terminé à la date prévue. Cette tâche a coûté jusqu'ici $4M et on prévoit qu'elle coûtera un autre million d'ici à la fin des travaux. On prévoit donc qu'en tout, cette tâche aura coûté $5M.

4) L'assemblage du sous-système mécanique commencera probablement un mois en retard et se terminera aussi un mois en retard. Il faut mettre en relief les retards prévus au moyen de pointillés.

5) L'assemblage du sous-système électronique a débuté un mois en avance et devrait être terminé un mois en avance.

6) L'achat du sous-système de contrôle de l'affichage est exécuté à 50% en ce qui touche les coûts. La date prévue d'achèvement a toutefois été reportée de deux mois.

7) L'intégration et les vérifications du système devraient commencer deux mois en retard à cause du retard accusé au niveau de la fabrication et de l'assemblage du sous-système mécanique.

8) À la fin du mois d'août, on prévoit que le coût total du contrat sera de $26M ($12.7M déjà engagés et une dépense de $13.3M de prévue), c'est-à-dire qu'il atteindra le coût de $26M. La date d'achèvement a toutefois été reportée d'un mois.

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CONTRACT PLAN AND REPORT FORM – FORMULE DE PROJET DE CONTRAT ET DE RAPPORT

CONTRACT TITLE – TITRE DU CONTRAT: GISMO DEVELOPMENT, ENGINEERING MODEL

CONTRACTOR – ENTREPRENEUR: ACME INDUSTRIES LTD.

FILE NO. – n° DU DOSSIER

SERIAL NO. – n° DE SÉRIE

TASK DESCRIPTION / DESCRIPTION DE LA TÂCHE	TASK DURATION IN MONTHS – DURÉE DE LA TÂCHE EN MOIS												TASK COST – COÛT DE LA TÂCHE		
	1 MAY / MAI	2 JUNE / JUIN	3 JULY / JUILLET	4 AUG. / AOÛT	5 SEPT.	6 OCT.	7 NOV.	8 DEC. / DÉC.	9 JAN. / JANV.	10 FEB. / FÉV.	11 MAR. / MARS	12 APR. / AVR.	PLANNED / PRÉVU À L'ORIGINE	ACTUAL / PRÉCISÉMENT	E.T.C. / À VENIR
MECHANICAL SUBSYSTEM / SOUS-SYSTÈME MÉCANIQUE													ALL NUMBERS IN MILLIONS / TOUS LES CHIFFRES REPRÉSENTENT DES MILLIONS		
MATERIAL PROCUREMENT / ACHAT DU MATÉRIEL													6M		
FABRICATION													3M		
ASSEMBLY / ASSEMBLAGE													2M		
ELECTRICAL SUBSYSTEM / SOUS-SYSTÈME ÉLECTRIQUE															
MATERIAL PROCUREMENT / ACHAT DU MATÉRIEL													2,5M		
FABRICATION													2,5M		
ASSEMBLY / ASSEMBLAGE													1M		
DISPLAY, CONTROL SUBSYSTEM / SOUS-SYSTÈME DE CONTRÔLE DE L'AFFICHAGE															
MATERIAL PROCUREMENT / ACHAT DU MATÉRIEL													2M		
FABRICATION													2M		
ASSEMBLY / ASSEMBLAGE													1M		
SYSTEM INTEGRATION / INTÉGRATION DU SYSTÈME													3M		
SYSTEM TEST / VÉRIFICATION DU SYSTÈME													2M		
PLANNED COST BY MONTH / COÛT PRÉVU POUR CHAQUE MOIS	1,5M	3,1M	3,6M	5,1M	5,1M	2,1M	1,5M	1M	1M	1M	1M		PLAN 36M		
ACT. PRÉCIS. / E.T.C. BY MONTH / PRÉVISION POUR CH. MOIS														ACTUAL COÛTS RÉELS	E.T.C. / À VENIR

Supply and Services Canada / Approvisionnements et Services Canada

DSS-MAS 9143-2 (4/81)

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CONTRACT PLAN AND REPORT FORM – FORMULE DE PROJET DE CONTRAT ET DE RAPPORT

CONTRACT TITLE – TITRE DU CONTRAT: GISMO DEVELOPMENT, ENGINEERING MODEL

CONTRACTOR – ENTREPRENEUR: ACME INDUSTRIES LTD.

FILE NO. – N° DU DOSSIER

SERIAL NO. – N° DE SÉRIE

TASK DESCRIPTION / DESCRIPTION DE LA TÂCHE	TASK DURATION IN MONTHS – DURÉE DE LA TÂCHE EN MOIS												TASK COST – COÛT DE LA TÂCHE		
	1 MAY MAI	2 JUNE JUIN	3 JULY JUILLET	4 AUG. AOÛT	5 SEPT. SEPT.	6 OCT. OCT.	7 NOV. NOV.	8 DEC. DÉC.	9 JAN. JANV.	10 FEB. FÉV.	11 MAR. MARS	12 APR. AVRIL	PLANNED / PRÉVU À L'ORIGINE	ACTUAL / PRÉCÉDEMMENT	E.T.C. / À VENIR
MECHANICAL SUBSYSTEM / SOUS-SYSTÈME MÉCANIQUE													ALL NUMBERS IN MILLIONS / TOUS LES CHIFFRES REPRÉSENTENT DES MILLIONS		
MATERIAL PROCUREMENT / ACHAT DE MATÉRIEL													6M	4M	1M
FABRICATION													3M	1,2M	1,8M
ASSEMBLY / ASSEMBLAGE													2M	–	2M
ELECTRICAL SUBSYSTEM / SOUS-SYSTÈME ÉLECTRIQUE															
MATERIAL PROCUREMENT / ACHAT DE MATÉRIEL													2,5M	2,5M	–
FABRICATION													2,5M	2,5M	–
ASSEMBLY / ASSEMBLAGE													1M	.5M	.5M
DISPLAY, CONTROL SUBSYSTEM / SOUS-SYST. DE CONTRÔLE DE L'AFFICHA.															
MATERIAL PROCUREMENT / ACHAT DE MATÉRIEL													2M	1M	1M
FABRICATION													2M	1M	1M
ASSEMBLY / ASSEMBLAGE													1M	–	1M
SYSTEM INTEGRATION / INTÉGRATION DU SYSTÈME													3M	–	3M
SYSTEM TEST / VÉRIFICATION DU SYSTÈME													2M	–	2M
PLANNED COST BY MONTH / COÛT PRÉVU POUR CHAQUE MOIS	1,5M	3,1M	3,6M	5,1M	5,1M	2,1M	1,5M	1M	1M	1M	1M		PLAN 26M		
ACT. / RÉÉL — E.T.C. BY MONTH / PRÉVISION POUR CH. MOIS	.5M	3M	4,1M	5,1M	4,6M	2,1M	1,1M	1,5M	1M	1M	1M	1M		ACTUAL COÛTS RÉELS 12,7M	E.T.C. / À VENIR 13,3M

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CONTRACT PLAN AND REPORT FORM – FORMULE DE PROJET DE CONTRAT ET DE RAPPORT

DSS-MAS 9143-3 (4/81)

CONTRACT TITLE – TITRE DU CONTRAT

CONTRACTOR – ENTREPRENEUR

FILE no. – nº du dossier	SERIAL no. – nº de série

TASK DESCRIPTION DESCRIPTION DE LA TÂCHE	TASK DURATION IN MONTHS – DURÉE DE LA TÂCHE EN MOIS												TASK COST – COÛT DE LA TÂCHE		
	1	2	3	4	5	6	7	8	9	10	11	12	PLANNED PRÉVU À L'ORIGINE	ACTUAL PRÉSENTEMENT	E.T.C. À VENIR
PLANNED COST BY MONTH COÛT PRÉVU POUR CHAQUE MOIS													PLAN		
ACT. PRÉSENT. / E.T.C. BY MONTH PRÉVISION POUR CH. MOIS														ACTUAL COÛTS RÉELS	E.T.C. À VENIR

EFFECTIVE: 1 APRIL 1987

Appendix " C "

TRAVEL & LIVING GUIDELINES

Meals and other expenses:	Canada	United States	NWT & Yukon
Breakfast	$ 6.40	$ 6.90	$ 8.20
Lunch	$ 8.50	$ 9.00	$10.10
Dinner	$16.45	$17.45	$19.25
Total Daily Meal Allowance	$31.35	$33.35	$37.55

INCIDENTAL EXPENSES

You may claim up to $6.00 per full and part calendar day in travel status when commercial accomodation is used and up to $4.00 when private accommodation is used.

SPECIAL TRAVEL SITUATIONS

When unusually high costs are incurred, such as during field research in the far north, actual expenses for incidentals and meals will be reimbursed, based on proof of payment, to the extent that the Minister considers the expenses claimed are reasonable and justifiable in the circumstances.

ACCOMMODATION

Single occupancy commercial accommodation of reasonable quality and comfortably equipped. LUXURY ACCOMMODATION IS NOT PERMITTED.

For private accomodation provided by friends or relatives: $13.50 CDN. per night in Canada and $13.50 U.S. per night in the U.S.A.

TRANSPORTATION

Intercity (air/rail/bus) transportation costs: use the most practical economy class public transporation.

Private vehicle mileage reimbursement shall not exceed the most practical economy class, public transit fare. Use of private vehicles not authorized for travel destination in excess of 200/320 km.

NS, NB, PEI, Ont. & BC	Man, Sask, Alta	NWT, Yukon	Que.	NFLD.
43/m	39.5/m	54.0/m	44.5/m	45.5
27/km	24.5/km	33.5/km	28/km	28.5/km

LOCAL TRANSPORTATION COSTS

Use public transit (airport buses, etc.) where practical.

Rent compact economy cars unless the number of passengers or load justifies a larger vehicle. (Personal accident coverage is not allowable)

RECEIPTS AND VOUCHERS

A statement indicating the names of travellers, places visited and when, length of visit and purpose of travel, must be submitted with each claim for travel and living expenses.

Receipts and vouchers for accomodation and transportation may be required to be submitted with claim. No receipt or voucher is required for private accommodation.

ENTERTAINMENT IS NOT AN ALLOWABLE COST

CONTINUATION - SUITE
PAGE 1 OF 1
Supply and Services Canada
Approvisionnements et Services Canada
1530. 23440-7-9148
Canada

APPENDIX XI

TECHNOLOGY TRANSFER SEMINAR
PHASE 1 REPORT
JANUARY 18 AND 20, 1989

1. INTRODUCTION

Two seminars were held to present and discuss the Phase I report of the Integrated Truck/Shovel Management System project. The seminars were held in Hinton, Alberta on January 18, 1989, and in Fernie, B.C. on January 20, 1989.

A total of fourteen coal mines and oil sands operations were invited to participate. Nine of the invited companies attended. The list of attenders is listed in Section 4.

The agenda for the seminars is included in Section 5.

2. SEMINAR TOPICS

The seminar presentation and discussion was structured along the lines of the original project categories:

- Simulation
- Dispatching
- Equipment Information
- Data Transfer
- Location Devices
- Data Base

3. SUMMARY OF COMMENTS AND QUESTIONS

The following is a compilation of the discussions held at both seminars. Most of the discussion centred on equipment information (production monitoring and mechanical monitoring), location devices (beacons and satellite location systems), and data transfer (data radio communications). The simulation, dispatching and data base areas did not generate as much discussion, probably attributable to the fact that these areas tend to be discussed less frequently in day-to-day operation of a mine.

Location Monitoring:

Interest in the satellite Global Positioning System (GPS) was expressed by some of the participants. GPS has the potential to locate a point in a mine to an accuracy of 1.5 metres. While this technology has interesting possibilities for locating trucks in the mine for dispatching and other purposes, there are several reasons why it was not included in the project at this time.

These reasons include the fact that the equipment is still exceedingly costly, and that it is not sufficiently rugged at this time. A further key consideration is that the satellite coverage is presently inadequate due to the delays in launching additional satellites. Finally, continuous location monitoring will generate considerable data for transmission over the data radio system, likely requiring one or more separate data radio channels.

Satellite communications for truck location monitoring will have to be assessed on the marginal increase in value in knowing the truck's location at every point along its route rather that at the key decision points, being road branches, shovels, dumps and crushers.

This area will be monitored for further development as the price decreases and ruggedness levels increase sufficiently to permit use on mining trucks.

The experience with beacons at Syncrude is that they are generally technically reliable, but the major problem area is managing the beacons. They need to be moved as the mining configuration changes, and the computer system needs to be updated to reflect these changes.

A participant from Quintette concurred that the difficulties with beacons presented in the seminar are consistent with their experiences.

Another participant asked what effect snow has on beacon operation. The response was that generally snow should have now significant effect. At the very high frequencies, say above 800 Mhz., precipitation can start to have some effect.

LORAN C as a vehicle location system was discussed. The experience with this system at a Nevada mine was related, where the accuracy of the system was only 500 feet or so. A test of a LORAN C based location system is being conducted on Vancouver Island by MacMillan Bloedel to track locations of logging trucks. This test to date was reported by a participant as being unsuccessful.

Computer System:

The computer language to be used for the integrated truck and shovel management system is to be finalized in a subsequent phase of the project. The current base for the Wenco Production Monitor & Control System (PMCS) is written in Pascal and C. A comment from a participant was that an Ontario mining industry association had suggested a standard to facilitate the exchange of programs. The recommendation

was that the C language be used, along with the UNIX operating system.

The choice of microprocessor, whether 80286 or 80386, will be made at a later phase of the project because of the constant change in computer hardware. It is envisioned that 80386 computers will be used.

Vehicle Monitoring - Mechanical

Comprehensive vehicle monitoring will be examined more closely in Phase 2. The reason for defering this to Phase 2 is that the technology in this area is still evolving, and that a joint CANMET/NRC project is being conducted at an INCO underground mine using a system made by Advanced Electronic Systems Ltd. That project will be examined for its applicability to truck/shovel operations. Additionally, the focus of the project has been on operations, whereas the comprehensive vehicle monitoring involves a different group of users.

The inclusion of tire management was discussed, with comments that it would be a desirable feature of the system. There would be value in knowing tire pressures in real time, transmitting a warning to the pit control if any truck's tire or tires fall below a certain critical level.

Regarding the vital signs monitoring recommended for the system (Ropec), a participant asked how the automatic engine shutdown would occur. The response was that the details of what decision sequence was not known in detail, but that this would be established by the supplier of that module.

Vehicle Monitoring - Payload

Truck weighing and shovel weighing was discussed as a feature with high potential payback. A participant pointed out that there is a scale system now available that can weigh trucks while they are in motion. Another case was cited where a mine is experimenting with a weighing system based on the pressure in the hydraulic pressure in the dump cylinder. One of the principal values of a truck weighing system is being able to monitor the weight of material going into the truck so that the shovel can load the truck to its optimal weight.

General:

The payback period is considered in selecting activities in the project. Payback period is difficult to determine in some cases because of the variability of value for different mines. An attempt to establish a range of costs and benefits for each project category is provided in the Phase I report.

The general concensus of participants was that Phase 2 of the project should proceed. Some mine representatives expressed particular interest and recommended that similar seminars be held in the future to report on subsequent phases of the project.

4. LIST OF ATTENDERS

Hinton Seminar:

Noel Billette - CANMET/NRC Ottawa
Bruce Stewart - CANMET/CRL Devon
Greg MacMaster - Cardinal River Coals Ltd.
Gary Daugela - Coal Mining Research Co.
Les Belanger - Suncor
Maurice Clark - Suncor
Jim Chalmers - Gregg River Resources Ltd.
Gary B. Gould - Gregg River Resources Ltd.
Andrew Kempe - Gregg River Resources Ltd.
Roger Shaneman - Gregg River Resources Ltd.
Paul Thomas - Gregg River Resources Ltd.
Ken Zaiachkowski - Gregg River Resources Ltd.
J.D. Whitehead - Luscar Sterco Ltd.
Mike Golder - Suncrude
Roy Logan - Syncrude

Fernie Seminar:

Tom Sneddon - Alberta Energy
Chris Guyver - Crows Nest Resources Ltd.
Roger Williams - Crows Nest Resources Ltd.
Matthew Cole - Fording Coal Ltd.
Ray Clucas - Quintette Coal Ltd.
Nancy Berzins - Westar Mining Greenhills Ops.
Arist Bruemmer - Westar Mining Greenhills Ops.
Steve Patterson - Westar Mining Greenhills Ops.
Robin Sheremeta - Westar Mining Greenhills Ops.
Alex Zaitsoff -Westar Mining Greenhills Ops.

5. SEMINAR AGENDA

Please see material appended

PRELIMINARY AGENDA

for

TECHNOLOGY TRANSFER SEMINAR

SUBJECT: Integrated Truck/Shovel Management System

PRESENTERS: CANMET & Wenco International Mining Systems Ltd.

LOCATION: Hinton, Alberta and Fernie, British Columbia.

DATE: January 18, (Hinton) and January 20, (Fernie).

TIME: 1:00 pm at both locations.

Topics for Presentation and Discussion

1. Purpose of Seminar
2. Summary of Project Background and Scope
   - Proposed System Components
3. Overall Project Structure
   - Participants
   - System Design Criteria
   - Project Methodology, ie. Phased Approach
   - Outline of Phase Content

4. Details of Phase 1

   - User Requirement Survey
   - Technology Evaluation
   - Conclusions & System Configuration
   - Features of each sub-system

     Simulation (short term and long term)

     Real Time Monitoring and Dispatching

     Equipment Information Systems

     Data Radio Systems

     Vehicle Location Monitoring

     System Database

5. Potential Benefits of Project
6. General Discussion
7. Summary of Audience Response